PART 1

Overview of Population Health Informatics

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CHAPTER 1
Emerging Need for Population Health Informatics

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KEY TERMS

- Affordable Care Act (ACA)
- American Recovery and Reinvestment Act of 2009 (ARRA)
- Cognitive fit theory
- Electronic health records (EHRs)
- Geographic information systems (GISs)
- Health information technology
- Population health
- Population health informatics (PopHI)
- Public health informatics (PHI)
- Social determinants of health

LEARNING OBJECTIVES

- Describe the growth of the Internet and social media in the 21st century.
- Define population health and its determinants.
- Distinguish between population and public health informatics.
- Assess the importance of social determinants of health data.
- Examine the intersection of technology and health care.
- List the challenges and opportunities related to population health informatics solutions.
- List the factors to consider in the adoption and implementation of population health informatics solutions.
QUESTIONS FOR THOUGHT

- What is the significance of social determinants of health to enhance population health outcomes?
- What opportunities does the growing usage of the Internet, mobile media, and social media have on health?
- How can stakeholders and consumers address the challenges related to implementation of population health informatics solutions in diverse settings?
- What opportunities do population health informatics solutions provide to improve population health outcomes?

CHAPTER OUTLINE

I. Population Health and Its Determinants
II. The Growth of the Internet and Social Media
III. The Intersection of ICTs and Health Care
IV. The Emerging Role of Population Health Informatics
V. Challenges and Opportunities Related to PopHI
VI. Adoption of PopHI Solutions
VII. SMAART: An Innovative PopHI Conceptual Framework
VIII. Conclusion

I. Population Health and Its Determinants

Drivers of health outside the traditional medical care include social, behavioral, and environmental determinants and need to be addressed to improve health and diminish health disparities. The section below highlights the significance of these factors in the improvement of population health outcomes.

Defining Population Health

Population health describes the health needs of a defined group's entire life span (Evans, Barer, & Marmor, 1994). Population health is a linking thread to help understand the determinants of health of populations (Evans et al., 1994). Social, economic, and physical environments; personal health practices; individual capacity; and coping skills all influence health status indicators. In turn, the health status indicators measure population health (Kindig & Stoddart, 2003). Population health is also considered as a summary measure that includes mortality and health-related quality of life (Field & Gold, 1998) (TABLE 1.1).

Public health services are typically provided by government agencies and include the core public health functions of health assessment, assurance, and policy setting. Several differences exist among the various aspects of Population health and public health, as shown here. Population health
<table>
<thead>
<tr>
<th>Definition of Population Health</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focuses on factors that influence the health of populations over the life course, variations in their patterns of occurrence resulting in actions, and policies to improve health and well-being of populations</td>
<td>Dunn, J. R., &amp; Hayes, M. V. (1999). <em>Toward a lexicon of population health.</em> Canadian Journal of Public Health, 90, S7.</td>
</tr>
</tbody>
</table>

- Is less associated with health departments at the government level (Stoto, 2013)
- Includes the healthcare delivery system and is seen as separate from governmental public health (Stoto, 2013)
- Is more than the sum of its individual parts (Stoto, 2013)
- Includes a broader array of the determinants of health than is typical in public health (Stiefel & Nolan, 2012)
- Has outcomes that go beyond state and local public health agencies and healthcare delivery systems (Ayana, 2016)
The Affordable Care Act (ACA) addresses population health in several ways (Affordable Care Act, 2011; see Figure 1.1). The ACA defined the affordable care organization (ACO), which includes clinicians, hospitals, and other healthcare organizations. They share mutual responsibility for the population of patients with the goal of improving health outcomes and reducing health costs and inefficiencies. A critical change is required by key stakeholders at the cultural, operational, and financial levels to improve population health. Collaboration among a variety of stakeholders (patients, providers, health plans, employers, government, the private sector, and the local community) is a vital component of the population health approach to strengthen care delivery and improve the well-being of individuals and families.

Determinants of Population Health

Multiple determinants, including educational, social, behavioral, and environmental factors, influence population health outcomes (Kindig & Stoddart, 2003; see Figure 1.2). Improving population health requires partners across many sectors including public health, healthcare organizations, community organizations, and businesses (Drummond & Stoddart, 1995). Population health data help organizations to do the following (Parrish, 2010):

- Identify at-risk populations
- Close communication gaps among individuals, public health agencies, and clinical care
- Identify cost-effective healthcare delivery models
- Provide access to available public health programs and services
- Improve population health decision making

Health and health problems result from a complex interplay of factors. Social determinants play a key role in the health of each individual. Social determinants of health have gained importance in recent health policy discussions. Existing literature has specified the importance of the social determinants of health in improving the health of populations. Education level, employment, income, family and social support, and community safety are all components of the social and economic determinants of health (County of Los Angeles Public Health, 2013). Unhealthy behaviors
are commonly associated with the lower social and economic position of a population or community. Poor education, lack of affordable housing, and insufficient income affect not just the individuals and families who have fewer resources, but also all the communities in which they live. Researchers estimate that access to quality medical care may prevent less than 20% of avoidable deaths. The remaining 80% of avoidable deaths are attributable to genetics (20%), and social, behavioral, and environmental determinants of health (60%; Taylor et al., 2016). Improvements in healthcare resources and other determinants are likely to have a large impact on prevention and the management of some illnesses (Starfield, 2006).

Gathering social determinants of health data would result in effective risk assessment to ultimately support population health management. It can help healthcare professionals to identify care gaps. Healthcare organizations can also get better insight into individual drivers of patient engagement and can match individuals to specific interventions, preventive services, or resources that are most likely to enhance outcomes. Social determinants of health have not been sufficiently recognized despite the knowledge of their impact on health outcomes and longevity. The interventions that address social, behavioral, and environmental determinants of health are also less developed. There is a need to generate integrated, evidence-based approaches to have a better impact on health outcome and lowering of healthcare costs. This gap has slowed health policymakers in promoting innovative models of care, even though these nonmedical determinants of health are worthy of attention.

Several challenges limit the integration of social determinants of health data. These impact evidence-based decision making, resulting in barriers to improving overall population health. Some of these challenges are (Robert Wood Johnson Foundation, 2016):

**FIGURE 1.2** Determinants of population health

Limited knowledge of what works best: Clinicians, healthcare providers, program operators, and researchers are utilizing data on social determinants of health to identify the best ways to collate and use these data so that guidelines can be evidence based.

Lack of standardization and tools: The absence of standard measures for collecting data on social determinants leads to inconsistencies. This limits the analysis and decisions that can be made using such data.

Limited knowledge in connecting patient, population, and public health data: Development of effective, targeted health interventions requires linking of data at multiple levels, from patient-level to population and social determinants of health.

Health systems need to understand their communities better: Community needs and requirements to create programs, policies, and interventions need to be well understood.

Sharing data across sectors: Data sharing and its utility in health decision making presents a fundamental challenge that involves issues of trust, system interoperability, sector, and workflows.

Identifying and developing the right technologies: Integrating social determinants of health data into electronic health records (EHRs) has also been a major challenge. The main alternative to EHRs for the collection, sharing, and use of social determinants of health data are custom technology, cloud-based technology, and geo-visual analytics.

Some of the outcomes facilitated by the analysis of social determinants of health data include the following (Falk, 2016):

- Increased advocacy to address health inequalities
- Better policymaking
- Improved health outcomes
- Cost-effective interventions
- Leadership action plans that positively impact safety, cost, and clinical outcomes
- Improved clinical decision making and evidence-based practice
- Improved practice guidelines

Different stakeholders have different interests, which are not often unified. Although policymakers focus on health policy decision making, advocacy groups typically focus on improving outcomes related to one disease or its determinant. If the goal is overall health improvement, individual groups working in silos are not productive (Kindig & Stoddart, 2003). Population health improvement as a goal creates an overarching need for a population health perspective that encompasses health outcomes across determinants.

II. The Growth of the Internet and Social Media

Information and communication technology (ICT) has continued to proliferate at a rapid pace. The beginning of the 21st century has ushered in the possibility of an unprecedented era of scientific discovery and promise. New ICTs are being explored to effectively and efficiently communicate with, engage, and educate the diverse public. Such technologies can be utilized as web-based apps, mobile phones, and alert systems. Technology continues to improve (Maynard & Harper, 2011). Computers
are now available at much lower, affordable prices. The Internet is a massive network, connecting millions of computers (FIGURES 1.3 and 1.4). The World Wide Web allows individuals to access information via a computer, mobile telephone, tablet, gaming device, or digital TV (Internet Live Stats, 2017).

**FIGURE 1.3** Internet users in the world

**FIGURE 1.4** Internet users by region
Currently, around 40% of the world's population has an Internet connection (Pew Research Center, 2016). As FIGURE 1.5 shows, North America has the highest Internet penetration rate (88%), and Africa has the lowest Internet penetration rate (27.7%) (Poushter, 2016; Internet World Stats, 2017). Nearly half of Internet users are from Asia (50.2%), as compared to 8.6% in North America.

Mobile and Internet technology use has become a daily, routine activity in most parts of the world. Internet use is proliferating, especially for obtaining health information (Atkinson, Saperstein, & Pleis, 2009). In addition to making and receiving calls, cell phones are widely used for multiple purposes including sending messages and capturing pictures and videos. Mobile health technologies constitute one of the most rapidly growing markets globally. Growth is primarily attributed to an increasing penetration of smartphones, tablets, and other mobile platforms, and the mHealth Solutions Market is predicted to be worth 59.15 billion USD by 2020 (Markets and Markets, 2017).

The use of mobile devices has transformed many aspects of health care. More than half of the Internet users in the United States (65%) reported using social networking sites in 2011 (Pew Research Center, 2016) (FIGURE 1.6). Facebook is the most popular social networking site globally (Capurro et al., 2014), with an estimated 1 billion active users in total, including 580 million daily users. Twitter, with 500 million users worldwide, detects and predicts events and sentiments by observing users' posts (tweets) in real time (Capurro et al., 2014). Social networking sites offer a range of possibilities for establishing multidirectional communication and interaction, as well as quickly monitoring public sentiment and activity (Capurro et al., 2014).

III. The Intersection of ICTs and Health Care

The advent of ICT has transformed healthcare delivery into patient-centered care. ICTs allow the delivery of healthcare services, particularly to isolated communities. Integration of clinical and nonclinical data sources by using ICTs to enhance population health outcomes across diverse geographic settings is a growing need.
Policymakers on a global scale are encouraging the use of such technologies to improve health and healthcare systems. Mobile health technologies, remote wearable devices, and sensors have demonstrated immense potential in preventing diseases and improving well-being in numerous settings (Capurro et al., 2014). Future technological innovation is going to keep transforming health care. Previously, technology played a minimal role in health, and healthcare professionals were the only way to take care of people (Friede & O’Carroll, 1996). Technology is now playing a significant role in health management information systems (HMISs), public health surveillance, geographic information systems (GISs), and EHRs and facilitates access to both public health programs and services. Technology is used to monitor patterns of illness and to detect emerging or imminent threats to public health (Araujo et al., 2009).

Public health professionals have been among the first users of information technology. Technology can help providers identify and address nonmedical factors that affect population health (Institute of Medicine, 1997). More and more organizations are beginning to record population-level data using cloud-based...
tools and technologies. Mobile devices including smartphones, tablet computers, and remote monitoring devices have ample potential for use in disease prevention, early risk identification, healthcare delivery, and timely support to populations living in diverse settings (Centers for Disease Control and Prevention, 2006). These emerging technologies present an opportunity to address global health challenges in both developed and developing countries. Healthcare organizations around the globe are forming technological infrastructures that enable several stakeholders to make better informed, faster decisions and individuals to better manage their health outside of the hospital setting (Deloitte, 2016). Innovative technologies cover multiple areas including surveillance for disease, environmental monitoring, pollution mitigation and prevention, behavior modification, screening, and chronic disease management (Eng, 2004). The wide-scale adoption of health information technology has enabled diverse stakeholders, such as providers, payers, and government agencies, to collaborate using new digital tools to improve the health of defined populations.

IV. The Emerging Role of Population Health Informatics

Informatics is the science of information, where information is defined as data with meaning (Bernstam, Smith, & Johnson, 2010). Informatics serves as a bridge across practitioners and professions to support collaboration and electronic communication. Informatics tools provide benefits to both administrative and clinical aspects of healthcare delivery and assist in collaborative practice by enhancing communication across team members. TABLE 1.2 lists some of the key global accomplishments in the field of health informatics.

<table>
<thead>
<tr>
<th>Year</th>
<th>Country</th>
<th>Key Accomplishments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1949</td>
<td>Germany</td>
<td>First professional organization for Informatics was founded</td>
</tr>
<tr>
<td>1950</td>
<td>United Kingdom</td>
<td>Medical Informatics initiated in the UK</td>
</tr>
<tr>
<td>1952</td>
<td>United States</td>
<td>First computer was used in clinical practice at the American Society for Clinical Pathology (Rappoport Arthur M-Bee)</td>
</tr>
<tr>
<td>1959</td>
<td>United States</td>
<td>First CT scanner was developed by Robert Ledley, one of the founding fathers of Informatics</td>
</tr>
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</table>
### IV. The Emerging Role of Population Health Informatics

<table>
<thead>
<tr>
<th>Year</th>
<th>Country</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>France</td>
<td>Training programs for Informatics in France began</td>
</tr>
<tr>
<td>1968</td>
<td>Brazil</td>
<td>Computers were first used in Medical care</td>
</tr>
<tr>
<td>1987</td>
<td>Hong Kong</td>
<td>Hong Kong Society for Medical Informatics (HKSMI) was established</td>
</tr>
<tr>
<td>1988</td>
<td>United States</td>
<td>American Medical Informatics Association (AMIA) established</td>
</tr>
<tr>
<td>1989</td>
<td>Switzerland</td>
<td>International Medical Informatics Association formed</td>
</tr>
<tr>
<td>1993</td>
<td>Nigeria</td>
<td>First International Working Conference on Health Informatics in Africa</td>
</tr>
<tr>
<td>1996</td>
<td>United States</td>
<td>A 2-year fellowship program was established by the Centers for Disease Control and Prevention</td>
</tr>
<tr>
<td>1997</td>
<td>Argentina</td>
<td>Biomedical Informatics group was established</td>
</tr>
<tr>
<td>2000</td>
<td>New Zealand</td>
<td>Health Informatics program established in New Zealand</td>
</tr>
<tr>
<td>2001</td>
<td>Canada</td>
<td>Canada Health Infoway was established</td>
</tr>
<tr>
<td>2002</td>
<td>Australia</td>
<td>Australasian college of health informatics established</td>
</tr>
<tr>
<td>2004</td>
<td>United States</td>
<td>Office of the National Coordinator for Health Information Technology was created</td>
</tr>
<tr>
<td>2005</td>
<td>United States</td>
<td>National Center for Public Health Informatics was created by CDC</td>
</tr>
<tr>
<td>2006</td>
<td>Saudi Arabia</td>
<td>Saudi Association for Health Informatics was established</td>
</tr>
<tr>
<td>2009</td>
<td>United States</td>
<td>The Health Information Technology for Economic and Clinical Health (HITECH) Act established</td>
</tr>
<tr>
<td>2017</td>
<td>India</td>
<td>Digital Health Technology Ecosystem incorporated into National Health Policy</td>
</tr>
</tbody>
</table>

Public Health Informatics

Public health informatics (PHI) is the science of applying information-age technology to serve the specialized needs of public health (Friede, Blum, & McDonald, 1995). PHI is a systematic application of information, computer science, and technology in the practice of public health (Yasnoff et al., 2000). It addresses three core functions of public health: (1) assessment of population health, (2) policy development, and (3) assurance of the availability of high-quality public health services. The scope of PHI expands beyond conceptualization and design and development (Yasnoff et al., 2000).

Members of the public health and informatics community discussed key PHI issues during the American Medical Informatics Association Meeting that was held in Atlanta during May 15–17, 2001 (Yasnoff et al., 2001). The issues were related to funding and governance; architecture and infrastructure; standards and vocabulary; research, evaluation, and best practices; privacy, confidentiality, and security; and training and workforce (Yasnoff et al., 2001). All stakeholders perceived the role of information systems to be beneficial in improving the health of individuals (Yasnoff et al., 2000). Some of the PHI-related challenges included developing integrated national public health information systems, enhancing integration efforts between public health and clinical care systems, and addressing the concerns of information technology on confidentiality and privacy (Yasnoff et al., 2001).

A follow-up PHI conference was held in 2011 to revisit the PHI agenda developed in 2001 (Massoudi et al., 2012). Three key themes were identified: the need to (1) increase communication and information sharing within the PHI community; (2) improve evaluation methods, competency training, and the use of public health; and (3) enhance leadership and coordination to move the field forward. Further recommendations included finding ways to strengthen prevention in the public health and clinical continuum and to build health at the community level (Massoudi et al., 2012).

Population Health Informatics

The U.S. HITECH Act of 2009 was designed to boost health information technology adoption nationwide. President Obama signed the act into law on February 17, 2009, as part of the American Recovery and Reinvestment Act of 2009 (ARRA) economic stimulus bill. Some of the key processes included care coordination, cohort management, clinician engagement, and reporting and knowledge management. Managing public health practice effectively and enhancing societal well-being require multiple resources that provide accurate, high-quality, and timely information. PHI focuses on population-level, preventive-based information. It also serves as an applied science in relevant government settings with a central goal of public health promotion (Yasnoff et al., 2000). PHI is a combination of medicine, public health, computer science, and information processing (Kukafka, 2005). It has also been defined as the application of ICTs in public health practice while integrating health research with information technology (Reeder, Hills, Demiris, Revere, & Pina, 2011). Application of PHI principles provides unprecedented opportunities to build healthier communities (Savel & Foldy, 2012).

A paradigm shift toward the area of population health informatics (PopHI) has begun. This shift is because of the increasing focus on social health determinants...
and use of technology in health care, combined with stakeholder initiatives including the ACA, HITECH Act, and other relevant reforms (Vest & Gamm, 2010). PopHI is the systematic application of information technologies and electronic information to the improvement of the health and well-being of a defined community or other target population (Kharrazi et al., 2017). For a health risk assessment to be conducted effectively at the population level, aggregate data are needed from a variety of sources including health facilities, social services, law enforcement agencies, departments of labor and industry, population-level surveys, and on-site inspections (O’Carroll, Yasnoff, Ward, Ripp, & Martin, 2003). PopHI can also be described as an integration of social determinants of health data sources (both clinical and nonclinical) by combining principles of ICT to enhance population health outcomes across diverse geographic settings (Joshi, Arora, & Malhotra, 2017; FIGURE 1.7).

The current need for PopHI arises from dramatic improvements in information technology, new pressures on the public health system, and changes in health care delivery. PopHI systems involve creation, storage, and processing of data to generate information and knowledge. PopHI facilitates data-driven, well-informed, evidence-based decision making for populations living in diverse settings. In addition to the informatics developments, elements of the PopHI system are a means to generate and process data to achieve meaningful information and knowledge about geographic areas that have concentrations of unfavorable health indicators or are composed of populations of underserved groups (Kharrazi et al., 2017). The development of such systems aims to help stakeholders gather timely and accurate information about entire population groups and permit assessment of disparities of health status among different populations (FIGURE 1.8).

PopHI also refers to the application of emerging technologies to improve the health of populations (Eng, 2004). Some of the challenges that exist in relation to the PopHI tools and technologies include privacy and security of patient data, confidentiality, quality, sustainability, and the existing technology divide (Eng, 2004; FIGURE 1.9).

**FIGURE 1.7** Intersections of population health, information systems, and computer science among populations in diverse geographic settings
Despite these challenges, health information technology, including mobile health technology, holds significant potential for engaging individuals in disease prevention and health promotion. It provides individuals with the necessary tools to record their data and make data meaningful. More research is needed to assess when, where, and for whom the population health technologies are efficacious. TABLE 1.3 lists the key comparisons between PopHI and PHI.

### V. Challenges and Opportunities Related to PopHI

Experts at a symposium sponsored by the National Library of Medicine identified six key domains of PopHI as significant (Kharrazi et al., 2017). Symposium attendees included national experts and leading researchers in academia, the public sector, provider organizations, and the information technology industry. These six domains were as follows:
### TABLE 1.3

<table>
<thead>
<tr>
<th></th>
<th>Population Health Informatics (PopHI)</th>
<th>Public Health Informatics (PHI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Context</strong></td>
<td>Both governmental and nongovernmental</td>
<td>Predominantly governmental context</td>
</tr>
<tr>
<td><strong>Common intervention targets</strong></td>
<td>Total population</td>
<td>Total population</td>
</tr>
<tr>
<td></td>
<td>Target population</td>
<td>Health departments</td>
</tr>
<tr>
<td></td>
<td>Healthcare organizations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Healthcare systems</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nongovernmental organizations</td>
<td></td>
</tr>
<tr>
<td><strong>Main operational goals</strong></td>
<td>Outreach and prevention</td>
<td>Assessment</td>
</tr>
<tr>
<td></td>
<td>Care integration</td>
<td>Prevention</td>
</tr>
<tr>
<td></td>
<td>Disease management</td>
<td>Assurance</td>
</tr>
<tr>
<td><strong>Action arm</strong></td>
<td>Population health organizations</td>
<td>Public health agencies</td>
</tr>
<tr>
<td></td>
<td>Care management organizations</td>
<td>Not-for-profit and nongovernmental organizations</td>
</tr>
<tr>
<td><strong>Key stakeholders</strong></td>
<td>Provider and payer systems</td>
<td>Federal, state, and local governments</td>
</tr>
<tr>
<td></td>
<td>Government and community</td>
<td></td>
</tr>
<tr>
<td><strong>Key information challenges</strong></td>
<td>Capturing nonmedical information</td>
<td>Expanding public health IT systems</td>
</tr>
<tr>
<td></td>
<td>Interoperability across sectors</td>
<td>Medical and public health interoperability</td>
</tr>
</tbody>
</table>


- **Interoperability and information infrastructure**: Having an interoperable platform that can facilitate data sharing can potentially help advance the agenda of PopHI.
- **Cross-organization collaboration**: Well-established programs or policies for population health data sharing across diverse stakeholders do not exist.
- **PopHI-based indicators and metrics**: There is a need to have an understanding of how advanced population health metrics can be derived from the health information technology systems.
- **Applying PopHI within integrated provider systems**: Current state-of-the-art tools represent an imbalance between focusing on the population vs. individual providers.
Computer science and informatics methods for population health: There is a great potential to utilize some of the computational methods from the field of computer science to address the challenges of population health data integration and analysis.

Integration of social and nonmedical factors into PopHI systems: Linking social and other nonmedical information with clinical data can enhance population health methods and models.

For each of the domains identified, existing challenges and potential opportunities were assessed, alongside future research directions to address them (TABLE 1.4).

**TABLE 1.4 Challenges and Opportunities Across Population Health Domains**

<table>
<thead>
<tr>
<th>Domains</th>
<th>Challenges and Opportunities</th>
<th>Research and Development Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interoperability and information infrastructure</td>
<td>Need for a clear, shared vision for a common, interoperable, and robust information infrastructure</td>
<td>Methods for securely and privately linking patient medical records across stakeholders</td>
</tr>
<tr>
<td></td>
<td>Need for effective patient identification methods to share data across systems</td>
<td>Promote a shared knowledge base for community health trends and population decision support</td>
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<tr>
<td></td>
<td>Inconsistent adoption of interoperability standards</td>
<td>Design end-user tools that incorporate usability methods and heuristics</td>
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<tr>
<td></td>
<td>Challenges associated with silo functions and service provisions</td>
<td>Foster the integration of social science data into PopHI’s overarching architecture</td>
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<tr>
<td>Cross-organization collaboration</td>
<td>Collaboration challenges among stakeholders</td>
<td>Consensus on what data to collect, integrate, and share as part of PopHI</td>
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<tr>
<td></td>
<td>Limited PopHI data use and exchange agreements</td>
<td>Discover and share new PopHI analytic solutions and models among stakeholders</td>
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<tr>
<td></td>
<td>Lack of aligned incentives</td>
<td>Define population health data-sharing methods using established standards</td>
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<tr>
<td></td>
<td>Instability of many partnerships between private and public organizations</td>
<td>Develop a set of metrics and decision support guidelines</td>
</tr>
<tr>
<td></td>
<td>Difficulty of blending medical, public health, and consumer-targeted interventions.</td>
<td>Create methods to assess the quality of shared data and techniques for linking disparate data sources</td>
</tr>
</tbody>
</table>
### V. Challenges and Opportunities Related to PopHI

<table>
<thead>
<tr>
<th>PopHI-based indicators and metrics</th>
<th>Applying PopHI within integrated provider systems</th>
<th>Computer science and informatics methods for population health</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding how new data sources, such as patient-generated data and unstructured EHR data, can be utilized</td>
<td>Lack of appropriate population health electronic quality measures</td>
<td>Heterogeneity and complexity of population health data sources</td>
</tr>
<tr>
<td>Need appropriate informatics methods for improving the reliability, accessibility, and comparability of such measures</td>
<td>Absence of proof-of-concept and return-on-investment of enterprise-level tool implementation</td>
<td>Privacy issues associated with population-level analytics</td>
</tr>
<tr>
<td>Develop a prioritized population/community report card</td>
<td>Up-to-date meaningful use policy, and a lack of governance structures for effective and efficient data sharing</td>
<td>Limited collaboration between health information technology and population health experts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lack of standardized data architectures for population health</td>
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<td>Develop and disseminate a &quot;grand computing challenge&quot; for PopHI</td>
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<td></td>
<td>Encourage collaboration between computer scientists and trigger the development of advanced, innovative methods</td>
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<td></td>
<td>Develop synthetic population-level datasets that can be shared freely</td>
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<td></td>
<td></td>
<td>Develop guidelines for large-scale data sharing as well as analytic frameworks for non-health researchers</td>
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<td></td>
<td></td>
<td>Advance interdisciplinary research in applied PopHI focus areas, such as change management and workflow reasoning</td>
</tr>
</tbody>
</table>

Develop actionable predictive models for population health metrics
Build a health information technology framework to capture and integrate patient-reported outcomes on the population scale
Create a methodology to align existing population health metrics across programs
Establish a framework to support the roll-out of new population-health–focused metrics by expanding collection of critical data elements
Integration of practice needs for population health data management and governance
Improvement of human factors and workflow issues for all stakeholders
Identification of a unifying framework for PopHI infrastructure and stakeholder incentives for adoption

V. Challenges and Opportunities Related to PopHI (continues)
VI. Adoption of PopHI Solutions

Apart from the challenges, opportunities, and research and development issues related to PopHI, the following 13 overarching themes of PopHI were identified (Kharrazi et al., 2017):

- **Policy alignment**: There is a need to align the PopHI strategies with desired outcomes that will facilitate adoption and implementation of appropriate PopHI solutions.
- **Data governance**: Data governance and data privacy policies need to be in place to ensure data sharing agreements so that it can further facilitate adoption and implementation of PopHI solutions.
- **Data quality**: A suboptimal rate of completeness, accuracy, timeliness, reliability, or validity of a data source can produce uncertainty when the data are incorporated into PopHI solutions.
- **Data management**: Differences in granularity and heterogeneity across various data sources create many data management challenges.
- **Sustainability and incentives**: Lack of funding and difficulty attracting new funding streams may affect the scalability of a project and limit the flexibility of its core business model.
- **Population metrics**: The lack of accurate and reproducible e-metrics may reduce the effectiveness of PopHI solutions.
- **Interoperability standards**: Limited PopHI standards and interoperability frameworks affect the development of new PopHI solutions.
- **Stakeholder collaboration**: If stakeholders do not collaborate effectively, this will produce suboptimal results.

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**TABLE 1.4 Challenges and Opportunities Across Population Health Domains (continued)**

<table>
<thead>
<tr>
<th>Domains</th>
<th>Challenges and Opportunities</th>
<th>Research and Development Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration of social and nonmedical factors into PopHI systems</td>
<td>Poor understanding of the information that needs to remain protected or confidential when using nonclinical data</td>
<td>Solutions need to integrate nonpersonal data to person-specific data</td>
</tr>
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<td></td>
<td></td>
<td>Develop population-based decision-support tools for both public health/community officials and clinicians</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Develop analytic tools that work across disparate population health data types</td>
</tr>
</tbody>
</table>

Tools and infrastructure: Limited PopHI data infrastructure and tools hinder the development of a robust health technology platform for population health.

Ethics and security: Concerns about the privacy, confidentiality, and security of data restrict the expansion of population-wide health information technology solutions.

Best practices and dissemination: Insufficient best practices for PopHI and limited dissemination mechanisms to introduce them among stakeholders have restricted the adoption of new PopHI solutions.

Education and training: Properly training PopHI experts in both payer and provider settings can help empower cross-organizational PopHI programs.

Evaluation methods: The development and evaluation of new PopHI methods are essential to advancing the science of population health.

The emerging field of PopHI addresses a broader-level population dimension as compared to PHI owing to increased adoption of value-based, technology-supported healthcare delivery paradigms (Moreno, Peikes, & Krilla, 2010). The HITECH Act has produced several desirable outcomes including increased use of information technology by healthcare providers (HITECH Act, 2009; Hsiao, Hing, & Ashman, 2014), data interoperability, integration, consolidation, and standards adoption (Centers for Medicare and Medicaid Services, 2012; Clinical Data Interchange Standards Consortium, 2016; Dolin et al., 2001; S&I Framework, n.d.), the creation of mega health data repositories (National Patient-Centered Clinical Research Network, 2015), and advances in the utilization of big data from multiple sources (Barrett, Humblet, Hiatt, & Adler, 2013). All of these factors have significantly improved the extent of the application of informatics to the population health domain.

Three structural barriers exist to the greater adoption of technology in healthcare. First, the necessary technology is not available; second, the technology exists but is not accessible; and third, technology is not always used, even when accessible. More effective collaboration is a crucial need to address the mechanism of data collection, its dissemination to various stakeholders, and their use of the data in healthcare decision making. An innovative sustainable business model for multisector collaboration is needed.

VII. SMAART: An Innovative PopHI Conceptual Framework

Health status and outcomes do not exist in isolation but are ingrained in a wider array of living conditions (Williams, Costa, Odunlami, & Mohammed, 2008). Including social context in the delivery of healthcare services can have a significant impact in the improvement of individual health. The larger social and economic policies and the economic resources available to the household can also importantly affect health. Improvement in population health involves the integration of complex, multidimensional data that enables diverse stakeholders (such as individuals, healthcare professionals, and policymakers) to identify patterns resulting in meaningful information (Jamison, 2006). There is a need to use the currently available knowledge to improve living conditions and the health of populations.
Defining SMAART
An innovative PopHI framework, Sustainable, Multi-sector, Accessible, Affordable, Reimbursable, Tailored (SMAART) (Joshi et al., 2017) has been proposed that aims to facilitate the integration of determinants of population health (social determinants and clinical data) to guide data-driven, evidence-based, PopHI-related programs, policies, and interventions to enhance population health outcomes across diverse geographic settings (FIGURE 1.10).

The SMAART Approach
The SMAART framework combines principles of data, information, and knowledge (DIK) (Chapter 2); human-centered design (HCD) (Chapter 6); cognitive fit theory (Dennis & Carte, 1998); information processing (Miller, 1956); and learning, behavioral, and humanistic theories (Boeree, 1998; Duffy & Jonassen, 1992; Spiro, Feltovich, Jacobson, & Coulson, 1988).

The principles of HCD involve (1) active involvement and understanding of users, (2) understanding task requirements, (3) appropriate allocation of function between user and system, (4) iteration of design solutions, and (5) multidisciplinary design teams. Understanding users is an important aspect of the HCD approach. An individual's ability to work with an HCD application is influenced by multiple demographic factors including age, literacy, spatial skills, and computer familiarity (Slocum et al., 2001). The user model gathers individuals' understanding regarding data, functions, domain, and mapping (Lauesen, 2005). HCD involves users' perspective to create a system that is useful and usable. Tasks classification helps to create useful applications. Common visual tasks performed by users include locating, identifying, distinguishing, categorizing, distributing, comparing, and correlating variables (Wehrend & Lewis, 1990). Interactions enable users to derive meaning and accomplish various analysis goals.

Better results are produced when the task requirement corresponds with the information presented (Joshi et al., 2012). This also improves system and task performance factors.
Cognitive fit theory reflects how the graphical output affects the decision processes (Dennis & Carte, 1998) and depends upon fit between information presentation and tasks used by the decision maker. Cognitive fit examines the best way in which a user’s task output can be presented (Dennis & Carte, 1998).

The principles of information processing theory (Miller, 1956) recommend that information be presented in a meaningful manner in small chunks (like 5–7 pieces of information). It also presents information in a structured format that is simple to understand. According to learning behavioral and humanistic theories, the information presented should be highly interconnected and relevant to the learner, and available in multiple content formats. Feedback should be provided based on responses (Boeree, 1998; Duffy & Jonassen, 1992; Spiro et al., 1988). The evaluation component assesses the process outcomes and the impact of PopHI tools and technologies on the cost of, quality of, and access to healthcare services (FIGURE 1.11).

**FIGURE 1.11** Theoretical approaches utilized in the SMAART framework
Components of the SMAART Framework

Some of the elements of the SMAART framework include the following (see FIGURE 1.12):

- **Multidimensional data:** Social determinants of health data are typically organized into a geospatial unit that often has three dimensions: (1) attribute (i.e., context), (2) spatial (i.e., geographic), and (3) temporal (i.e., time). The attribute (context) component relates to issues of interest such as social data, environmental data, and health data. The spatial (geographic) component includes data with location attributes (e.g., address, region, or country) and can provide insight into how and where to obtain essential services. The temporal (time) component records the time of the observation and enables users to learn from the past to predict, plan, and build the future. The SMAART framework facilitates the integration of social determinants of health data such as socioeconomic factors, the physical environment, health behaviors, clinical assessment, and knowledge, attitude, and practice (FIGURE 1.13). The data are generated into meaningful information to derive an individual/community risk profile, based on existing guidelines and evidence.

- **Data management component:** This component includes several modules such as data recording and storage, data, data validation techniques, and data transformation by making data available in a format that is ready to be analyzed.

- **Data analysis component:** This component includes statistical analysis capabilities to help analyze multisectoral data at both the individual and aggregate levels.
Visualization component: The visualization component contributes to displaying meaningful information in various formats including tables, charts, graphs, and maps. This component allows individuals to actively interact with the data to conduct specific analyses and visualize the information based on the needs of the individual or organization.

Intervention component: This component involves several programs, policies, and interventions that can enhance population health outcomes across diverse geographic settings.

Evaluation component: The evaluation component includes system evaluation, process outcomes, and both clinical and nonclinical outcomes.

The SMAART framework can be operationalized as an interactive, a stand-alone, an Internet, or a mobile-enabled platform that (1) facilitates transmission of data and information regarding the health status of the individual/community, (2) interprets data and information using previously established knowledge and/or wisdom and use of evidence-based standards, (3) addresses the specific needs of the individual/community, (4) provides timely feedback to the consumer addressing...
specific requirements, and (5) uses regular repetition of the feedback loop. Prior research has shown the need to have customized technology solutions to address the gaps that exist in the integration of social determinants of health data and clinical data to enhance population health outcomes.

Several recommendations have been proposed for PopHI interventions to be successful (Kharrazi et al., 2017). Barriers such as cost, poor infrastructure, lack of or limited Internet access, and inadequately trained human resources often prevent or delay the adoption of technology in healthcare (Buitenhuize, Zelenika, & Pearce, 2010). Overcoming these barriers is crucial if the potential of technology for global health is to be realized. Decisions about implementation of a health technology solution should combine a range of considerations, from cost per unit to how to encourage uptake, to whether a technology can work in a particular setting and the best way to achieve implementation. This presents an urgent need to implement sustainable, low-cost, accessible, and affordable technology-enabled health solutions to meet the needs of local communities, especially those living in low-resource settings.

**VIII. Conclusion**

Effective use of data determines the extent to which population health stakeholders can sufficiently address societal health concerns. There is an increasing need for tools and technologies that facilitate knowledge construction (Bhowmick, Griffin, MacEachren, Kluhsman, & Lengerich, 2008). Technical constraints, including connectivity, bandwidth provision, and reliability, also need to be taken into account during PopHI implementations (Panth & Acharya, 2015). Expanding the development and dissemination of health data standards and vocabulary tools is critical to improving access. New and upcoming health technologies have shown tremendous value in reducing healthcare costs while improving well-being. Although such technologies are being developed and utilized in several domains of care, intensive research is required to fully explore their potentials, challenges, and opportunities (Eng, 2004). There is an urgent need for PopHI training with an emphasis on competence in population health, data analytics, systems thinking, evaluation, and transdisciplinary approaches to problem solving, communication, leadership, advocacy, and technology. Economic evaluations also need to be taken into consideration when designing, developing, implementing, and evaluating PopHI interventions.

The present century has unraveled a plethora of scientific innovations and discoveries with the potential for better outcomes. Emerging technologies provide enormous opportunities for population health improvement (Eng, 2004). These also present an opportunity for addressing global health challenges in both developed and developing countries. The adoption of population health technologies will require optimal research in the field of PopHI.

**References**


References


Chapter 1 Emerging Need for Population Health Informatics


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