HHS Public Access

Author manuscript

*J Safety Res*. Author manuscript; available in PMC 2021 June 01.

Published in final edited form as:

*J Safety Res*. 2020 June ; 73: 189–193. doi:10.1016/j.jsr.2020.02.018.

# Advancing injury and violence prevention through data science ⋆

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## Abstract

**Introduction:** The volume of new data that is created each year relevant to injury and violence prevention continues to grow. Furthermore, the variety and complexity of the types of useful data has also progressed beyond traditional, structured data. In order to more effectively advance injury research and prevention efforts, the adoption of data science tools, methods, and techniques, such as natural language processing and machine learning, by the field of injury and violence prevention is imperative.

**Method:** The Centers for Disease Control and Prevention's (CDC) National Center for Injury Prevention and Control has conducted numerous data science pilot projects and recently developed a Data Science Strategy. This strategy includes goals on expanding the availability of more timely data systems, improving rapid identification of health threats and responses, increasing access to accurate health information and preventing misinformation, improving data linkages, expanding data visualization efforts, and increasing efficiency of analytic and scientific processes for injury and violence, among others.

**Results:** To achieve these goals, CDC is expanding its data science capacity in the areas of internal workforce, partnerships, and information technology infrastructure.

**Practical Application:** These efforts will expand the use of data science approaches to improve how CDC and the field address ongoing injury and violence priorities and challenges.

### Keywords

Data science; Injury; Violence; CDC

⋆The Journal of Safety Research has partnered with the Office of the Associate Director for Science, Division of Injury Prevention, National Center for Injury Prevention and Control at the CDC in Atlanta, Georgia, USA, to briefly report on some of the latest findings in the research community. This report is the 60th in a series of "From the CDC" articles on injury prevention.

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## 1. Background

Injuries, such as drug overdose, suicide, and motor-vehicle crashes, are the leading cause of death for people aged 1–44 years in the United States, and among the top 10 causes of death for Americans of all ages (CDC, 2020a). Each year, over 240,000 people die from injuries and approximately 30 million sustain injuries serious enough to require treatment in an emergency department (CDC, 2020a).

In recent years, rates of deaths due to many forms of injury and violence–drug overdose, suicide, homicide, road traffic crashes, and falls–have increased, leading to recent declines in life expectancy in the United States (Xu, Murphy, Kockanek, & Arias, 2020). Beyond rising mortality, each year injuries and violence contribute to substantial morbidity as well as social and economic costs in the United States. The total annual lifetime medical and work loss costs of injury and violence has been estimated to be $671 billion, with $214 billion associated with fatal injuries and $456 for nonfatal injuries (Florence, Simon, Haegerich, Luo, & Zhou, 2015; Florence, Haegerich, Simon, Zhou, & Luo, 2015).

To address the important and growing public health challenge of injuries and violence, data are needed to define the burden, identify risk and protective factors, develop and test interventions, and effectively disseminate and ensure widespread adoption (Hanson, Finch, Allegrante, & Sleet, 2012). Current injury and violence data challenges include the lack of real-time information, inability to identify emerging health threats, limited capability to target services, increasingly prevalent health misinformation, declining participation in and lack of representativeness of traditional data systems, and fragmentation of electronic health records and clinical and administrative data systems.

However, with advances in technology, data have evolved and recently have increased in volume, variety, and velocity (Austin & Kusumoto, 2016). The volume of new public health data being created each year continues to grow. For injury, this includes administrative data; electronic health records; prescription data; data from non-health sectors, such as law enforcement, transportation, and social service providers; and internet and social media content. The variety of the types of useful data also has advanced beyond organized data and structured data that have traditionally been used in public health practice. This includes unstructured written text and notes, images (e.g., gifs, memes), video content, and sensor-derived information (e.g., data from watches and phones). Data are being created and effectively stored exponentially faster than ever before. Whereas some traditional public health systems like the National Vital Statistics Systems mortality data are made available annually and with a one-year or more time lag, some systems now generate data in near real time.

In order to capitalize on this explosive growth of data to advance injury and violence prevention efforts and to make this data analyzable, useful, and timely, the field needs to advance the application of data science tools, methods, and techniques, such as machine learning and natural language processing.

Data science is an emerging and rapidly evolving field. Academic, industry, and governmental organizations (National Institutes of Health, 2018) typically have defined the

field of data science by two consistent features: (a) a multidisciplinary nature blending methodological techniques from computer science, statistics, and various subject matter domains; and (b) a focus on large, complex, or otherwise novel data sources. The robust adoption of data science in public health is nascent, but growing. In this article, we discuss efforts and plans by the Centers for Disease Control and Prevention's (CDC) National Center for Injury Prevention and Control (the Injury Center) to advance injury and violence prevention through data science.

## 2. NCIPC pilot data science projects

The Injury Center has conducted several pilot projects to explore how data science can be used to advance injury and violence prevention efforts.

For example, early detection of emerging health threats is a significant challenge for injury and violence prevention. Consequently, the Injury Center has worked to explore the potential of new data sources and novel methodologies to aid in recognizing emerging health concerns earlier. In one project, Injury Center scientists documented that youth suicide games, which can spread rapidly online, are detectable in web and social media data up to nine months prior to identification by traditional media outlets and public health agencies (Sumner et al., 2019). Similarly, Injury Center scientists identified that increases in posts about emerging opioids causing overdose are observable on drug forums prior to increases in fatality rates from such substances (Bowen, O'Donnell, & Sumner, 2019). These pilot projects suggest that, with the application of appropriate methodologies, novel data sources can potentially help identify emerging factors influencing injury.

The Injury Center also has explored the nature of health information and misinformation related to injury topics. For example, based on the recognition that many individuals now increasingly obtain health news and information from digital sources, Injury Center scientists studied the factors influencing dissemination of positive and protective information about mental health online, helping to advance the scant knowledge base on positive health information related to suicide (Sumner, Bowen, & Bartholow, 2020). Ongoing Injury Center work seeks to understand both the nature and impact of protective health information as well as the characteristics of health misinformation related to injury and violence.

Other data science pilot projects have explored areas ranging from linkage of diverse administrative data for an improved understanding of risk of injury (Sumner et al., 2016; Wu et al., 2019), evaluation of machine learning models for geographic prediction of violent crime (Bowen et al., 2018), and analysis of natural language in real-time electronic health records to aid in accurate assessment of injury trends (Zwald et al., 2020).

Furthermore, the Injury Center has recognized the need to grow and modernize its Web-based Injury Statistics Query and Reporting System (WISQARS™) (Ballesteros, Webb, & McClure, 2017; https://www.cdc.gov/injury/wisqars/). WISQARS™ initially was developed in 1999 as a user-friendly online system that allowed the public 24/7 access to injury surveillance data and customizable reports. The early WISQARS™ applications gave data tables as results from queries. In early 2018, the first WISQARS™ data visualization

application was released, which allows for fatal injury data exploration in a new interactive visual format. Since that time, the Center also has released additional data visualization applications on direct comparisons of fatal injury data and one that uses nonfatal data (CDC, 2020a).

## 3. The injury center's data science strategy goals

These data science projects resulted in the Injury Center's leadership recognizing the potential public health benefits for expanded data science work. In early 2019, the Injury Center's Office of Strategy and Innovation convened an internal working group comprised of a diverse group of leaders and subject matter experts from across the Center to develop the Center's first Data Science Strategy for Injury and Violence Prevention. Guiding principles for the development of the strategy included concepts such as the following:

### (1) Expand the availability and utility of more timely data for injury and violence prevention

Data timeliness is increasingly important for more real-time feedback on whether current prevention policies, programs, practices, and funding efforts are adequately reducing injury and violence rates. Many current, publicly available data systems for injury and violence outcomes are delayed by one or more years. Furthermore, the degree to which injury and violence data indicators are upstream of morbidity and mortality is also of growing interest. Although measures such as fatalities and hospitalizations are important and objective measures of diseases, such events often represent permanent or extreme health events for individuals and do not capture the full spectrum of the impact of injuries and violence. Ideally, public health prevention, monitoring, and deployment of interventions occurs upstream of or before such health consequences. Tasks under this concept could include efforts that:

- Accelerate data collection, processing, and reporting from established public health data systems, such as mortality data systems.
- Evaluate and invest in new data sources (such as administrative, business, or web-based data) as well as new data collection modalities (such as online surveys).
- Develop forecasting and other advanced methodologies combining information from multiple data sources via machine learning models to estimate injury and violence burden in real-time.
- Advance the use of electronic health records for public health surveillance, including expanding the number of syndrome definitions available for injury and violence monitoring via the National Syndromic Surveillance Program (NSSP). NSSP's Biosense platform receives data from approximately 70% of the nation's emergency departments visits within 24 hours for analysis (CDC, 2020b). This would involve testing new methods, techniques, and tools such as natural language processing and machine learning to more routinely and efficiently utilize electronic health record information for public health monitoring.

### (2) Improve rapid identification of health threats and response to communities

The identification of emerging and novel health threats remains a challenge for injury and violence prevention, as traditional public health surveillance and data systems are not generally designed to capture these types of threats. The deployment of field response teams for any cause of injury depends on early identification of clusters of injury or violence. Leveraging novel and timely data sources such as online data sources have shown promise in identifying emerging health threats prior to their identification in more traditional data systems (Sumner et al., 2019; Bowen et al., 2019). Tasks under this concept could include efforts that:

- Advance the application of natural language processing methodologies to Injury Center text-based data systems as well as novel streams of data.
- Improve modeling approaches to detect space–time clusters of illness and injury for more rapid and accurate outbreak detection.
- Increase the timeliness of insights gained from Injury Center field investigations through expanding electronic data collection and automation of analyses and reporting.

### (3) Increase access to accurate health information and prevent health misinformation.

The importance of accurate and protective health information is a key component of public health efforts to combat the increasing proliferation of health misinformation (Southwell et al., 2019), defined here as false content that is intentionally, unconsciously, or mistakenly circulated. The use of social media has now supplanted print newspapers as a primary source of news (Shearer, 2018). Many health professionals and the general public increasingly access health information online and often in an environment that lacks clarity on what entities are trusted and scientifically valid. Relatedly, content and information fostering stigma, further prevent access to care and worsen health outcomes for areas such as injury and violence prevention (Hatzenbuehler & Pachankis, 2016). There also is a need to understand how misinformation diffuses through formal and informal networks as well as effective strategies to counter misinformation. Tasks under this concept could include efforts that:

- Quantify the prevalence and characteristics of both accurate information as well as misinformation related to injury and violence prevention.
- Evaluate how health information, norms, and stigma diffuse through communities and networks.
- Leverage this information to expand awareness of evidence-based prevention policies, practices, and programs.

### (4) Enhance the usefulness of current data systems through improving data linkage

While many leading injury and violence prevention data systems collect robust information on the occurrence of injuries and violence, information on antecedent risk and protective factors, and other contextual variable are often not included. These limitations prevent an understanding of the complete picture of the burden of injury and hinder prevention

strategies. In part, these constraints can be addressed through expanded linkage of multiple data sources, which will aid in unlocking new insights about risk and protective factors, identify opportunities for prevention interventions, and improve evaluating the effectiveness of intervention strategies. Tasks under this concept could include efforts that:

- Advance the availability of linked data and data system interoperability by building on existing and scalable injury and violence data systems, such as the National Violent Death Reporting System (NVDRS) and the State Unintentional Drug Overdose Reporting System (SUDORS), which are state-based surveillance systems that pool more than 600 unique data elements from multiple sources (CDC, 2020c; 2020d).
- Formally evaluate the benefits of linked data systems for injury prevention in state and local settings.
- Improve awareness, understanding, and best practices related to the legal and ethical considerations for data linkage through collaboration with organizations active in this area.

### (5) Share information in compelling, useful, and accessible ways

Data visualizations can be used to facilitate an understanding of complex information that is used to inform research, health policy, and resource allocation; and they can be a central component of shaping individual health behaviors. Additional work is needed to expand the Injury Center's visualization of injury data. This will improve communication of injury findings, enable enhanced data exploration, and allow for overlay of data from multiple sources. Additionally, there is a need for conducting research to better understand what forms of visualization best advance policy, programs, and public understanding of injury data. Tasks under this concept could include efforts that:

- Advance data visualization techniques for injury information, increase visualization of morbidity data, and study the effectiveness of data visualization approaches to achieve policy, programmatic, and practice objectives.
- Develop more robust dashboards and interactive tools to enable a comprehensive understanding of injury and violence topics and the comparison of data across multiple sources.
- Modernize communications strategies with the addition of interactive data visualizations and digital storytelling to the Injury Center website.
- Develop internal data visualization tools to allow Injury Center scientists to improve the efficiency of data exploration and analytic tasks and capacitate staff to enhance visualizations used in scientific products.

### (6) Advance ethical practices for data science for injury and violence prevention

While new data sources and methods for advancing health have evolved rapidly, these developments have also raised important ethical questions for scientists and health practitioners. Important areas for consideration include transparency and interpretability of machine learning models, maintenance of user privacy in large scale online data, data

security and risk of identification with linked data, and bias present in some administrative data sources (Rajkomar, Hardt, Howell, Corrado, & Chin, 2018; Moreno, Goniu, Moreno, & Diekema, 2013). Tasks under this concept could include efforts that:

- Conduct systematic reviews to comprehensively assess the current state of use of data science methods for injury and violence prevention research and practice.
- Convene diverse stakeholders to articulate best practices for injury and violence prevention given the complexities of such work.
- Work to ensure benefits from advances in technology related to injury prevention are allocated equitably among the public.

### (7) Increase efficiency of analytic and scientific processes for injury and violence prevention

Key data systems for injury and violence prevention contain increasing amounts of unstructured data, including natural language, and often rely upon human coding of records to identify cases and perform certain reporting functions. This incurs significant time and human resources. The Injury Center also routinely conducts and updates systematic reviews for a range of injury and violence topics; these efforts entail manual coding of thousands of scientific articles per year. Opportunities exist to better utilize natural language in these datasets and systematic reviews to enable faster querying of records for case identification and automating some manual coding tasks. Tasks under this concept could include efforts that:

- Build tools using natural language processing and machine learning to improve the efficiency of scientific tasks for these key data systems to improve the timeliness and quality of reporting and increase scientific output.
- Facilitate the use of data science tools to streamline repetitive processes such as article classification for updating injury-related systematic reviews, de-identification of health information, and cleaning of variables.
- Disseminate novel methods and tools for increasing analytic efficiency externally to state and local public health partners, grantees, and researchers to support their work.

### (8) Evaluate promising state and local data science efforts for injury prevention and expand the capacity of state and local health partners in data science methodologies

Many leading CDC data systems and programs for injury and violence prevention began as local efforts. Opportunities exist to identify and expand innovations being pursued by state and local public health departments both in injury and violence surveillance, prevention, and response programs. Those that are evaluated and deemed effective should be expanded and scaled up. Tasks under this concept could include efforts that:

- Identify and evaluate novel local public health efforts that employ data science tools, methods, and techniques.

- Quantify the cost effectiveness of such innovations and determine feasibility for broader scaling.
- Help to scale effective practices nationally.
- Strengthen the capacity of state and local health partners to apply data science methodologies to their work such as through technical assistance to health departments on data systems and health surveillance methodologies.

## 4. Growing NCIPC's internal data science capacity

For the Injury Center to achieve its data science goals, the Center has been working to expand its capacity in the areas of: (a) internal workforce, (b) partnerships, and (c) information technology (IT) infrastructure.

*Workforce* development involves further increasing awareness among leadership and subject matter experts about how data science approaches can be used to enhance how the Injury Center works with and uses data. This will be achieved through internal trainings, expert presentations, and group and individual discussions. Additionally, the Injury Center recently established a Data Science Team that includes statisticians, computer scientists, programmers, and health scientists. This team will consult and collaborate with Center programs and subject matter experts to advance the science in priority topic areas through data science. The team will lead and support data management and processing, database architecture, linkage of disparate datasets, improvements in automation, development of techniques to work with novel data sources (e.g., unstructured, web-based, "big" data), applications of data science models and algorithms (e.g., machine learning, natural language processing, predictive analytics, other advanced analytic approaches), and creation of innovative data visualizations and tools (e.g., data dashboards, interactive mapping). The Injury Center could also increase formal training opportunities through fellowship programs and exchange opportunities with scientists from academic, non-governmental, and private sector organizations.

Internal *partnerships* are being created across NCIPC to connect subject matter experts to data scientists to determine research questions, identify appropriate data sources, develop analytic plans, interpret results, and more effectively communicate findings. Strong partnerships with other CDC centers and offices provide additional opportunities to learn from each other's data science experiences and to better understand how non-injury programs are applying data science to their topic areas and needs. Partnerships external to CDC can provide access to new information and exchanges of innovative methods, techniques, and tools. Examples include collaborations with academic universities, state and local health departments, non-governmental organizations, and private sector companies.

*Infrastructure* improvements will include working with the Injury Center and Agency's informatics experts to enhance the IT environment for the receipt, storage, access, analysis, and visual depiction of large and disparate data sources. The Injury Center's new Office of Informatics is charged with standardizing and expanding tools to share, clean, process, and analyze data in automated ways. This includes developing best practices for the storage of

increasing amounts of injury- and violence-related data and expanding access to cloud-based environments to grow capacity for more rapid querying of large volumes of data. As part of this work, the Injury Center Office of Informatics is ensuring compliance with current information security standards, and working to enhance access to software, programs, tools, and products for data science activities such as interactive data visualizations.

The Injury Center's data science goals and activities align with CDC's Information Technology Strategic Plan (CDC, 2017) and Public Health Data Modernization Initiative (CDC, 2019). Both efforts aim for more timely public health data, improved IT tools and infrastructure, and a strengthened CDC workforce in data science, informatics, and IT systems.

The Injury Center will look for opportunities to leverage its new data science activities and experiences to all injury and violence priority topic areas. This will be done through adapting models, tools, and programs created from Center projects; and disseminating findings through appropriate channels such as reports, publications, presentations, and online content and applications.

## 5. Conclusions

Injury and violence contribute to significant morbidity, mortality, and social and economic costs each year. Given the substantial impact on individuals, families, and communities across the United States, preventing injury and violence is a public health imperative. Embracing data science as a core part of injury and violence prevention unlocks innovative tools, methods, and techniques to improve our understanding of the occurrence and risk and protective factors for injury and violence, develop and test prevention interventions, and support communities in their efforts to reduce injury and violence and foster community resilience for better health.

## Biographies

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