Design, Application, and Actionability of U.S. Public Health Data Dashboards: A Scoping Review

Gretchen Stahlman, Itzhak Yanovitzky, Miriam Kim

Submitted to: Journal of Medical Internet Research
on: August 11, 2024

Table of Contents

Design, Application, and Actionability of U.S. Public Health Data Dashboards: A Scoping Review

Gretchen Stahlman[1*] PhD; Itzhak Yanovitzky[2*] BA, MA, PhD; Miriam Kim[2] BA

[1]School of Information Florida State University Tallahassee US
[2]School of Communication & Information Rutgers University New Brunswick US
[*]these authors contributed equally

Corresponding Author:
Gretchen Stahlman PhD
School of Information
Florida State University
142 Collegiate Loop
Tallahassee
US

Abstract

Background: The COVID-19 pandemic highlighted the importance of robust public health data systems and the potential utility of data dashboards for ensuring access of diverse groups of stakeholders and decision-makers to critical public health data. As dashboards are becoming ubiquitous, it is imperative to consider how they may be best integrated with public health data systems and the decision-making routines of diverse audiences. However, additional progress on the continued development, improvement, and sustainability of these tools requires the integration and synthesis of a largely fragmented scholarship regarding the purpose, design principles and features, successful implementation, and decision-making supports provided by effective public health data dashboards across diverse users and applications.

Objective: This scoping review provides a descriptive and thematic overview of national public health data dashboards, including their purpose, intended audiences, health topics, design elements, impact, and underlying mechanisms of use and usefulness of these tools in decision-making processes. It identifies gaps in the current literature on the topic and provides the first-of-its-kind systematic treatment of actionability as a critical design element of public health data dashboards.

Methods: The scoping review follows the PRISMA-ScR guidelines. The review considers English-language, peer-reviewed journal articles, conference proceedings, book chapters, and reports that describe the design, implementation, and/or evaluation of a public health dashboard published between 2000-2023. The search strategy covers scholarly databases (CINAHL, PubMed, MEDLINE, and Web of Science) as well as grey literature sources and snowballing techniques. An iterative process of testing for and improving intercoder reliability was implemented to ensure that coders are properly trained to screen documents according to the inclusion criteria prior to beginning full review of relevant articles.

Results: The search process initially identified 2,544 documents including articles located via databases, grey literature searching and snowballing. Following the removal of duplicate documents (n=1416) and non-relevant items (n=839), 289 met the inclusion criteria. These documents are categorized into three groups: US case studies (n=90), non-US case studies (n=126), and literature reviews and background information (n=73). Through a lens of actionability assessment, the analysis shows that the scientific literature is considerably fragmented with respect to the goals, design, use, usefulness, and impact of these tools. However, actionability is shown to be a function of the process used to develop, evaluate, and sustain dashboards for the benefit of users.

Conclusions: The scoping review analyzes the goals, design, use, usefulness, and impact of public health data dashboards. The review also informs the continued development and improvement of these tools by identifying gaps and synthesizing current practices and lessons emerging from the literature on the topic. There is a significant opportunity for future research to advance both scholarship and practice regarding the design, deployment, and sustainability of actionable dashboards by addressing the gaps.

(JMIR Preprints 11/08/2024:65283)
DOI: https://doi.org/10.2196/preprints.65283

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?

✓ **Please make my preprint PDF available to anyone at any time (recommended).**
Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.
Only make the preprint title and abstract visible.
No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✓ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**
Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain v
Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in <a href="http

Original Manuscript

Design, Application, and Actionability of U.S. Public Health Data Dashboards: A Scoping Review

Abstract

Background: The COVID-19 pandemic highlighted the importance of robust public health data systems and the potential utility of data dashboards for ensuring access of diverse groups of stakeholders and decision-makers to critical public health data. As dashboards are becoming ubiquitous, it is imperative to consider how they may be best integrated with public health data systems and the decision-making routines of diverse audiences. However, additional progress on the continued development, improvement, and sustainability of these tools requires the integration and synthesis of a largely fragmented scholarship regarding the purpose, design principles and features, successful implementation, and decision-making supports provided by effective public health data dashboards across diverse users and applications.

Objective: This scoping review provides a descriptive and thematic overview of national public health data dashboards, including their purpose, intended audiences, health topics, design elements, impact, and underlying mechanisms of use and usefulness of these tools in decision-making processes. It identifies gaps in the current literature on the topic and provides the first-of-its-kind systematic treatment of *actionability* as a critical design element of public health data dashboards.

Methods: The scoping review follows the PRISMA-ScR guidelines. The review considers English-language, peer-reviewed journal articles, conference proceedings, book chapters, and reports that describe the design, implementation, and/or evaluation of a public health dashboard published between 2000-2023. The search strategy covers scholarly databases (CINAHL, PubMed, MEDLINE, and Web of Science) as well as grey literature sources and snowballing techniques. An iterative process of testing for and improving intercoder reliability was implemented to ensure that coders are properly trained to screen documents according to the inclusion criteria prior to beginning full review of relevant articles.

Results: The search process initially identified 2,544 documents including articles located via databases, grey literature searching and snowballing. Following the removal of duplicate documents (n=1416) and non-relevant items (n=839), 289 met the inclusion criteria. These documents are categorized into three groups: US case studies (n=90), non-US case studies (n=126), and literature reviews and background information (n=73). Through a lens of actionability assessment, the analysis shows that the scientific literature is considerably fragmented with respect to the goals, design, use, usefulness, and impact of these tools. However, actionability is shown to be a function of the process used to develop, evaluate, and sustain dashboards for the benefit of users.

Conclusions: The scoping review analyzes the goals, design, use, usefulness, and impact of public health data dashboards. The review also informs the continued development and improvement of these tools by identifying gaps and synthesizing current practices and lessons emerging from the literature on the topic. There is a significant opportunity for future research to advance both scholarship and practice regarding the design, deployment, and sustainability of actionable dashboards by addressing the gaps.

Keywords: dashboard; scoping review; public health; design; development; implementation; evaluation; user need.

Introduction

Background

The disjointed public health response to the COVID-19 pandemic in the U.S. highlighted the critical importance of having robust public health data systems in place and the potential utility of data dashboards for ensuring timely and unrestricted access to critical public health data [1, 2]. The ubiquitous and prominent use of dashboards to chronicle the progression and public health response to the COVID-19 pandemic has increased the appeal of these tools to a broad and diverse range of decision-makers, including public health leaders and professionals, health care providers, community leaders, policymakers, and advocates [3, 4]. Data dashboards are frequently touted as cost-effective means to share and access public health and other types of publicly available data because they transform complex data into intuitive information displays, afford instantaneous and near-universal access of multiple stakeholders to data-based insights, and allow users to explore data on their own to answer questions that are important to them [5-8]. They are also increasingly recognized for their democratizing potential, both in terms of making data available to a wider and more diverse range of audiences and ensuring that diverse stakeholders, particularly those who are less privileged and/or are most likely to be impacted by how data are interpreted and used in decision-making, have the power and opportunity to shape what and how data are used in this context [9].

Aims and Contributions

As public health data dashboards are poised to become more integral to public health decision-making at the local, state, and federal levels in the U.S., it is imperative to proactively consider how they may be best designed, implemented, improved, and sustained to promote sound, equitable, and effective public health policies and practices [3, 10]. Progress in this direction is currently impeded by the fragmented nature of research on this topic, specifically the lack of coherence regarding effective dashboard design principles and practices, as well as the mechanisms, factors, and supports that make dashboards usable and useful to diverse user groups and across health and decision-making contexts [3, 7, 10, 11]. Previous reviews of the literature on use of data dashboards in public health have generally focused on identifying and assessing the utility of key design features of dashboards, but were limited to specific public health application such as COVID-19 [2, 12], food and nutrition systems [13], infectious diseases [14], and environmental hazards [15], or were limited in focus to specific dashboard design features such as data visualizations [16] or usability [4]. Thus, a systematic review of the literature that is broader and more comprehensive in the scope of health topics and applications considered, and which goes beyond design-related research questions to consider different goals of data dashboards (e.g., alert, educate, persuade, etc.), theories of action (or how dashboards are presumed or expected to work), and outcomes of use (including impact indicators), has significant potential to advance the scientific study of data dashboards as instruments for promoting sound health-related decisions, policies, and practices.

An additional unique contribution of this scoping review is the explicit focus on *actionability* as a critical feature of effective public health data dashboards. There has been a growing interest in the question of what makes public health data dashboards *actionable*, i.e., ensuring they provide an optimal match for both purpose and use [17-21]. Yet, actionability as applied to public health data dashboards is not yet fully defined or sufficiently operationalized to inform the design and implementation of such tools. Ivanković and colleagues [22], for example, defined data dashboard actionability according to seven features: (1) knowing and clearly stating the desired consumers of the information; (2) selection and presentation of appropriate indicators; (3) clearly stating the sources of data and methods used to generate indicators; (4) demonstrating variation over time and linking changes to public health interventions; (5) providing as high a spatial resolution as possible

to enable consumers to evaluate local risk; (6) disaggregating data to population subgroups to further enable evaluation of risk; (7) providing narrative information to enhance interpretation of the data by the consumer. This *functional conception* understands actionability as a function of both usability and degree of match between data and users' information needs, which is intuitive, but may not be equally applicable across audiences and settings [20]. Other scholars in this space offer a *behavior-centered conception* of actionability [21]. In their view, to be actionable, dashboards must prompt or trigger users to act on data by being integrated, via behavioral design, into users' data use practices or routines such as assessing performance on tasks or progress on goals. Finally, there are those who advocate for a *decision-centered conception* of actionability, whereby data dashboards are considered actionable to the extent that they provide data, analyses, and/or forecasts (e.g., predictive analytics) allowing decision-makers to make an informed choice among alternatives [19, 20, 23]. It is possible that all three conceptions are relevant to the definition and operationalization of actionability, and an important objective of this scoping review was to extract, integrate, and synthesize dimensions and measures of actionability, as well as conditions that improve actionability, that emerge from the empirical literature on public health data dashboards.

Methods

Review Methodology and Protocol

This scoping review was designed to generate both descriptive and thematic account of the purpose, intended audiences, range of health topics, design elements and characteristics, usability and usefulness measures, theories of action, and logistics of developing, implementing, and sustaining public health data dashboards based on information available from published U.S. case studies. Given the considerable diversity in research questions and methodologies employed across disciplines and fields to study public health data dashboards, a scoping review of the literature is most appropriate for producing a systematic evidence synthesis [24]. This study followed the PRISMA-ScR, which is the most up-to-date and advanced approach for conducting and reporting scoping reviews [25]. We briefly describe below the methodological processes implemented. Further details are available in the published protocol [26].

Selection Criteria, Sources, and Search Strategy

For the purposes of this scoping review, we defined 'public health data dashboard' as a publicly accessible, web-based, interactive, and regularly updated information management and data visualization tool that displays and tracks population health indicators, metrics, and/or data points. This definition is inclusive of a broad range of population health-relevant data such as epidemiological surveillance but excludes the use of data dashboards in clinical and/or healthcare organizations as well as dashboards incorporated into patient portals. Accordingly, the eligible population of relevant publications consisted of all English language, full text, peer-reviewed journal articles, conference proceedings, book chapters, and reports that describe the design, implementation, or evaluation of a U.S. public health dashboard published between 2000-2023. Given the rapid advancements in dashboard technology in recent years, considering a broader historical perspective can be useful for determining what, if anything, changed over time regarding the design philosophies and theories of action guiding the development and implementation of these tools. To ensure adequate and inclusive representation of empirical studies, no methodological orientation restrictions were imposed as selection criteria.

The search methodology (see published protocol for full details [26]) involved a series of steps to minimize potential errors in our search strategies that negatively affect the quality and validity of this scoping review [27]. First, in collaboration with a research librarian, we searched both the MeSH database and keywords listed in recently (2019 and onward) published journal papers on the topic of

public health data dashboards to identify the most relevant keywords and terms for searching for relevant publications that meet our inclusion criteria. In the next step, we followed an established procedure [28] to experiment with different combinations of databases and search queries to optimize the recall (sensitivity) and precision (specificity) of our search strategy. Given the aims of this scoping review, we opted for a search strategy that maximizes coverage, that is, will increase the likelihood of identifying all or as many as possible relevant publications. Accordingly, we searched CINAHL, PubMed, Medline, and Web of Science databases in June 2023 for published research reports using the least restrictive validated search query ([“dashboard” OR “data dashboard” OR “information visualization” OR “data visualization”] AND [“public health” OR “population health”]). These databases were selected because they were identified, via rigorous testing, as providing optimal coverage of research published across a broad range of disciplines and fields [29]. We conducted supplementary searches of gray literature using the same search query to search OpenGrey for additional documents that met all selection criteria.

Data Charting

The list of themes and variables used for data abstraction is presented in Textbox 1. This list was created following an iterative process of reviewing the strategies and instruments used in previous similar reviews, consultations with an expert advisory group composed of public health data dashboard creators, and pretesting of the instrument with a randomly drawn sample of publications included in the review using the same procedure described above for validating the screening and selection procedure, including training on the task and tests of intercoder agreement (see published protocol for full details [26]).

Textbox 1. List of data extraction elements.

Study identifiers:
- Metadata (title, authors, journal, year of publication, and keywords)
- Study type (e.g., descriptive, exploratory, and explanatory)
- Research methodology
- Study focus (e.g., development, implementation, and evaluation)
- Geographic location (country)

Data characteristics:
- Data sources
- Health topics
- Type of data (e.g., epidemiological, health services, and behavioral)
- Populations represented in the data
- Indicators or metrics selected for visualizations
- Data level of granularity (e.g., national, state, county, and city)

Dashboard design characteristics:
- Stated goals or purposes of the dashboard (e.g., tracking or monitoring)
- Design philosophy cited (e.g., user-friendly, functional, and co-design)
- Design process (e.g., iterative and collaborative)
- Dashboard features (e.g., customization and search functionalities)
- Data visualization tools (e.g., maps, graphs, and tables)

Users and usability:
- Intended audiences
- Public access (open, restricted/limited, requires registration)
- Dissemination channels (e.g., social media, news outlets, email, and listserv)
- Reported use- or usability-related barriers or challenges

Logistics or operation:
- Ownership or hosting

- Source of funding
- Software tools (commercial and open source)
- Data updating and quality assurance protocols
- Technical support (e.g., user manuals, training, and customer service option)

Performance and usefulness or impact evaluation:

- Evaluation methodology
- Use or usability indicators captured (e.g., website analytics and user ratings)
- Impact indicators or other evidence of impact
- Explanations given for observed effects or impact (or lack of)

Data were extracted and recorded using a survey instrument designed to capture a range of closed-ended, multiple, and open-ended responses to facilitate standardized coding by multiple coders. Quantitative data were cleaned, harmonized, and properly labeled prior to being analyzed using IBM SPSS Statistics (Version 29) for generating descriptive statistics. Open-ended text entries were reviewed and analyzed collectively by the authors and organized in common themes to produce additional insights.

Results

A total of 2529 documents (peer-reviewed journal papers, conference proceedings, and book chapters) were initially retrieved by implementing the search procedure. After the removal of duplicate results (n=1386), and the addition of "grey literature" sources (n=10) and additional papers identified through snowballing of sources cited in other related literature reviews (n=5), a total of 1128 documents were retained for manual screening and 216 met the study's definition of a case study of a public health dashboard. Of these, 127 documents were excluded because they were case studies of public health data dashboards in countries outside the U.S. and therefore beyond the scope of the current scoping review. However, these items were retained for the purpose of conducting a future complementary scoping review to compare findings across international boundaries. Accordingly, a total of 89 U.S.-based case studies of public health data dashboards that met all selection criteria were included in the scoping review. The reasons for exclusion are detailed in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram (Multimedia Appendix 1), and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews reporting checklist is presented in Multimedia Appendix 2.

Each published case study of a U.S.-based public health data dashboard was coded using the data charting instrument (see Box 1). All coders (n=5) first received training on the task and then were provided with a random sample of 10 documents to code. Agreement among coders was assessed using Krippendorff's α [29], and the omnibus test result was significantly lower (α=.37) than the acceptable standard (α=.70). Coders then received additional training on the task and then independently coded a fresh set of 10 randomly selected documents. Intercoder agreement was reassessed and reached an acceptable standard (α=.78), with any ambiguities regarding coding resolved via a full team review and consensus.

Study Characteristics

A list and basic characteristics of the case studies included in the review is provided in Multimedia Appendix 3. Articles reviewed were published in 60 different outlets between 2004 and 2023, and most commonly appeared in *American Journal of Public Health* (8% [7/89]), *Journal of the American Medical Informatics Association* (7% [6/89]), *Journal of Public Health Management and Practice* (6% [5/89]), and *JMIR Public Health and Surveillance* (3% [3/89]). While the case studies

included in this scoping review were published over a period of 19 years (2004-2023) and are quite diverse in terms of health topics and intended users of dashboards, a majority (69% [61/89]) were published after 2019, coinciding with the COVID-19 pandemic. Indeed, 40% [35/89] of the case studies included in the review directly address some aspect of COVID-19 and public health.

There was a considerable variation in the type of studies included in the scoping review. Over half provided a description of the dashboard developed, including sources of data, design features, and technical details (55% [49/89]). About a quarter were more exploratory in nature, reporting the results of usability tests conducted with users and any subsequent refinement of the dashboard developed [26% [23/89]). A smaller number of case studies were classified as explanatory in that they included qualitative or quantitative assessment of the degree to which use of the dashboard was associated with effects on users' knowledge, decisions, or actions (15% [13/89]). A handful of cumulative case studies (5% [4/89]) considered lessons learned from comparing the development or implementation of a dashboard across settings or user groups. Regarding case study methodology, 10% (9/89) of the case studies included in the review employed quantitative methods, 37% (33/89) used qualitative methods, and 31% (28/89) combined mixed methods. About 20% (18/89) of the case studies reviewed were a description of a dashboard and the process of developing the dashboard.

Overall, then, case studies that systematically assess use, usefulness, and outcomes of using public health dashboards remain scarce even as the volume of published empirical research on the topic has sharply risen in recent years. This is also evidenced in the types of information frequently provided in the case studies reviewed. Information typically reported includes features or functionalities of the dashboard (91% [80/89]), sources of data used (89% [78/89]), and the logistics of developing and deploying the dashboard (71% [62/89)]. Less frequently reported is information pertaining to assessing use or usability of the dashboard (30% [26/89]), results of usability tests (22% [19/89]), any form of impact evaluation (19% [17/89]), or dissemination procedures (16% [14/89]). This distribution may reflect authors' choice of what information to include given space limitations and the absence of standards for reporting on dashboards, but it may also point to the paucity of efforts to assess the usefulness of these tools to public health decision makers.

Dashboard Hosting and Funding Source

The dashboards represented in the scoping review were more likely to be hosted on university websites (26% [23/89]), compared to federal government sites (10% [9/89]), sites maintained by non-profit or philanthropic organizations (8% [7/89]), state government sites (7% [6/89]), and independent (non-affiliated) hosts (7% [6/89]). A handful (less than 5%) of dashboards were hosted by municipalities or health care industry organizations. Website hosting information was unavailable for 33% of case studies reviewed (29/89), primarily because a web address for the dashboard was not provided.

Most of the dashboards studied (41% [36/89]) were funded by U.S. government health agencies (e.g., CDC, NIH, and AHRQ), followed by universities (22% [19/89]) and philanthropic organizations (15% [13/89]), with grants being the most common mechanism for funding the development and deployment of public health dashboards (44% [39/89]). Funding information was not provided for 31% (27/89) of the case studies reviewed. However, where funding information was available, 53% (19/36) of federally funded studies utilized federal data sources, compared to other data sources such as state agencies (36% [13/36]), research organizations (33% [12/36]), media sources (31% [11/36]), and local agencies (17% [6/36]). Taken together, these findings suggest that both data and dashboard governance are predominantly handled through government agencies and data infrastructures. In broader terms, institutional actors such as government agencies, universities,

and philanthropic organizations are the primary funders, developers, and hosts of public health data dashboards in the U.S., presumably because they possess the necessary resources and expertise to create and maintain these tools.

Topic, Purpose, and Intended Users

The list of public health topics covered by the dashboards represented in this review is included in Multimedia Appendix 3. For the purpose of synthesis, case studies of public health dashboards were grouped by type of data used and purpose of presenting the data. Since dashboards frequently incorporate different types of data and may serve multiple purposes, there was a considerable overlap among the categories of this variable (which explains why the percentages reported below exceed 100%). Considering this, the overall primary function or purpose of the dashboards reviewed was surveillance and monitoring. Epidemiological surveillance (e.g. incidence of illness, risk factors, etc.) was the most common purpose (57% [51/89]), followed by health outcomes surveillance (e.g., births, deaths, life expectancy, quality of life measures (38% [34/89]), tracking utilization of health services (e.g. proportion of population screened or immunized; 33% [29/89]), and exploration or analysis of sources or causes of health disparities (e.g. social determinants of health; 30% [27/89]). Behavioral surveillance such as tracking self-reported attitudes and behaviors (14.5% [13/89]), news and social media content surveillance (12.5% [11/89]), policy or legislation surveillance (10% [9/89]) and tracking availability of health care facilities or health services in a certain geographical area (17% [15/89]) were less common. These differences may be attributed to the limits imposed by the types of population health data available to dashboard developers, which are predominately epidemiological and health services data. About 22% (20/89) of the dashboards reviewed provided predictions of future trends (often based on data extrapolation) or likely effects (positive or adverse) of changes such as increasing access to health care insurance or services in a community, which may enhance their actionability potential.

Recognizing that public health data dashboards are often created to serve multiple audiences, the intended users of dashboards identified by the authors of the case studies reviewed were most commonly public health decision makers (e.g. public health departments, officials; 38% [34/89]), followed by policymakers (e.g. agency, state, city administrators; 34% [30/89]), researchers (e.g. researchers, analysts, academics; 32% [28/89]), practitioners (e.g. clinicians, healthcare administrators, public health professionals, first responders; 32% [28/89]), and the general public (e.g. citizens, media, schools, etc.; 30% [27/89]). By comparison, public health advocates were less likely to be referenced as potential intended users of dashboards across the case studies included in the review (13.5% [12/89]). No information regarding intended users was provided in 17% of the analyzed studies (15/89).

Since dashboard actionability is primarily a function of match between audience needs and purpose, a multiple-response cross-tabulation analysis was conducted to probe the degree to which the purposes for which dashboards were created vary by the needs of different intended audiences, specifically researchers, policymakers, decision makers and practitioners, and the general public (see Table 1). The results of this analysis reveal very little differences, if any, in purpose by intended users. Thus, case studies of dashboards designed for epidemiological surveillance were equally likely to identify researchers, policymakers, and public health decision makers or practitioners as intended users, and the same was true for dashboards designed tracking and comparing health outcomes and those designed to highlight the effects of social determinants of health. By comparison, case studies of dashboards designed for tracking access and use of health services were more likely to identify members of the general public as intended audience compared to researchers, policymakers and public health decision makers. This inconclusive pattern of findings suggests that the design of

actionable dashboards tailored to specific audience groups is not a common practice. Conversely, it may reflect dashboard designers' belief that the dashboards they design are universally usable and useful for diverse audience groups and for diverse purposes.

Table 1. Cross tabulation with multiple response sets of dashboard's purpose by intended users identified in case studies of U.S. public health data (N=89)

Purpose (tracking and surveillance)	**Intended Users**								
	Researchers	**Policymakers**	**Decision makers**	**Practitioners**	**Advocates**	**General public**	**Developers**	**N/A**	**Total**
	***n* (%)**	***n* (%)**	***n* (%)**	***n* (%)**	***n* (%)**	***n* (%)**	***n* (%)**	***n* (%)**	***n***
Epidemiology	16(57%)	18(60%)	21(62%)	14(50%)	5(42%)	21(78%)	4(80%)	6(40%)	51
Behavior	3(11%)	8(27%)	6(18%)	6(21%)	2(17%)	3(11%)	0(0%)	5(33%)	13
Policy	2(7%)	4(13%)	3(9%)	4(14%)	1(8%)	2(7%)	0(0%)	1(7%)	9
Information	3(11%)	5(17%)	5(15%)	4(14%)	2(17%)	5(19%)	0(0%)	1(7%)	11
Access to services	3(11%)	7(23%)	5(15%)	4(14%)	3(25%)	9(33%)	2(40%)	2(13%)	15
Use of services	5(18%)	7(23%)	10(29%)	8(29%)	4(33%)	9(33%)	3(60%)	6(40%)	29
Outcomes	11(39%)	13(43%)	13(38%)	10(36%)	6(50%)	12(44%)	3(60%)	7(47%)	34
SDOH	10(36%)	10(33%)	14(41%)	11(39%)	5(42%)	9(33%)	2(40%)	7(47%)	27
Predict	7(25%)	5(17%)	5(15%)	2(7%)	1(8%)	4(15%)	1(20%)	0(0%)	11
Prescribe action	0(0%)	0(0%)	3(9%)	1(4%)	2(17%)	4(15%)	0(0%)	1(7%)	9
Total Count	28	30	34	28	12	27	5	15	N=89

[a] Dichotomy group tabulated at value 1 (answer yes)
Note: percentages represent percentages within sets, not percent of total cases. SDOH = social determinants of health

Data Source, Focus, and Representation

The case studies of dashboards included in the review primarily integrate data from federal agency sources (e.g. CDC, AHRQ; 49% [44/89]), followed by state agencies (e.g. state department of health; 33% [29/89]), health care facilities (e.g. administrative data such as ER records, hospitalizations; 26% [23/89]), media (e.g. news, social media; 21% [19/89]), and research organizations (e.g. university research; 20% [18/89]). Aggregated patient or clinical data (16% [14/89]), municipal data (15% [13/89]), insurance claims data (8% [7/89]) were less frequently utilized.

The type of data featured in dashboards was primarily epidemiological data (e.g. incidence of disease, illness, events such as drug overdoses; 54% [48/89]), health services data (e.g. data about services provided by certified health providers such as hospitalization, ambulatory care, screens, medications, and immunizations; 54% [48/89]), clinical data (e.g. data related to patient diagnosis, exposures, laboratory tests, etc.; 46% [41/89]), and health outcomes data (e.g. births, deaths, life expectancy, quality of life; 43% [38/89]). Behavioral data (e.g. self-reported measures of beliefs, attitudes, and behaviors, including consumption; 21% [19/89]), media data (e.g. news coverage, social media posting; 6% [5/89]), and environmental risk data (5% [4/89]) were less frequently integrated into the dashboards reviewed, presumably because such data are not routinely collected or readily available to creators of public health data dashboards.

The same pattern of findings emerged regarding the range of public health issues addressed by the dashboards studied (see Multimedia Appendix 3 for a complete list): common categories of issues

included risk factors (e.g. chemical exposure, infectious diseases, tobacco use; 47% [42/89]), disease incidence (e.g. obesity, diabetes; 25% [22/89]), and health disparities (e.g. access and/or utilization of health/medical services; 19% [17/89]), but less frequently social determinants of health (6% [5/89]) or behavioral or public opinion insights (6% [5/89]). Most dashboards (91% [81/89]) focused on a single topic, with about 40% of the dashboards studied (35/89) exclusively focused on the topic of COVID-19.

Regarding representation, the dashboards studied afforded users access to varying levels of international (17% [15/89]), national (46% [41/89]), state (53% [47/89]), and hyperlocal (e.g. city/town, county; 70% [62/89]) public health data indicators, with the greatest degree of overlap between state and local data (42% [37/89]). There were also notable variations in the populations represented in the data utilized by dashboards. Patient populations (54% [48/89]) and general population (52% [46/89]) were most frequently represented in the data utilized compared to provider populations (8% [7/89]) and data that exclusively represents vulnerable populations (11% [10/89]). As may be expected, vulnerable populations were more likely to be represented in dashboards focused on health disparities and social determinants of health (60% [6/10]) than dashboards focused on other aspects or dimensions of public health (e.g., risk factors and utilization of health services).

Dashboard Design Process and Design Principles

Based on the information provided by authors, we determined that the design of dashboards included in the review was most frequently driven by the intended purpose or goal of using the dashboard (*functional design*, represented in 33% of case studies [29/89]) or the needs or preferences of users (*user-centered design*, represented in 32% of case studies [28/89]), but less frequently to facilitate or support a particular decision-making process (*decision-centered design*, represented in 15% of case studies [13/89]). No clear design philosophy was discussed by authors in 35% of the analyzed case studies (31/89).

Variations regarding the collaborative nature, if any, of the design process ranged from creator-driven (no input from users, represented in 44% of case studies [39/89]), through creator-driven with user feedback (30% of case studies [27/89]), and to a partnership-based or a co-design process (26% of case studies [23/89]). Reported collaborations on dashboard development were overwhelmingly scientific collaborations with external experts or teams of developers (51% [45/89]), and less likely to involve collaborations with funders (11% [10/89]), community representatives (11% [10/89]), or industry (6.5% [6/89]). Over one third of all case studies (36% [32/89]) did not reference any collaboration.

Given that relatively few case studies involved user feedback or collaboration, data visualization choices were presumably made without input from users in many cases. Nevertheless, data visualization tools referenced include graphs/charts (78% [69/89]), maps (61% [54/89]), timelines (40% [36/89]), and tables (36% [32/89]), with information about visualization tools missing from 8% of case studies analyzed (7/89). Interactive customization options referenced include selecting or sorting cases by one or more indicators (61% [54/89]), selecting or grouping cases by location (52% [46/89]), sorting or grouping by time (38% [34/89]), sorting or grouping by demographic characteristics (28% [25/89]), and a searching function (11% [10/89]). Information regarding customization was missing or ambiguous in 23% of case studies (20/89). In 30% of case studies (27/89), authors indicated that integrating health data with social determinants of health data for the same group or locality (e.g., rural health indicators by rural access to broadband internet) was possible.

Data visualizations implemented in the dashboards studied could be most frequently disaggregated spatially or geographically (58% [52/89]), followed by temporally or time (e.g. year, month, etc.; 36% [32/89]). Other common disaggregation options reported include demographics (e.g. age, gender, race, ethnicity, etc.; 27% [24/89]), and socioeconomic factors (e.g. education, income, etc.; 24% [21/89]). No disaggregation options were referenced in 23% of case studies analyzed (20/89), and disaggregation by contextual factors (e.g. environmental hazards, health services availability, and genomic and biological factors) was available in less than 15% of case studies analyzed. Interestingly, we found no reference to data storytelling, simulations, and other more interactive forms of audience engagement with data in the case studies reviewed.

Use, Usability, and Usefulness

To determine whether a dashboard was still active at the time of conducting our review, we used the uniform resource locator (URL) provided by authors, either in the text of the publication or any supporting materials. URLs of dashboards were not provided in 41% of the case studies analyzed (36/89). We were able to confirm that 47% of all dashboards (42/89) were still active at the time of our review and that 12% (11/89) were inactive or could no longer be accessed due to broken links. This appears to be related less to time passed since the publication of the case study and more to do with relevance or data availability. Thus, while recent, 45% (16/35) of the case studies of COVID-19 dashboards were no longer available or accessible at the time of producing this scoping review and many of those that remain accessible have not been recently updated, as COVID-19 cases and death data reporting has been discontinued by CDC with the end of the Public Health Emergency in May 2023. In addition, based on information provided in the case study or inspecting the provided URLs, we were able to determine whether users had unrestricted or conditional access to dashboards included in the analysis. Open or unrestricted public access to dashboard was observed in 46% of all cases (41/89) whereas conditional access (e.g. having to register as a user before granted access) was observed for 14% of all cases (12/89).

Only sparse information was provided in the case studies reviewed regarding how users were to learn about the availability and intended use of data dashboards, with such information not reported for 75% of cases (67/89). Dissemination channels referenced when such information was provided include webinars/training/outreach (15% [13/89]), social media posts (6% [5/89]), newsletters (5% [4/89]), news items, email distribution lists, and blogs (3% each [3/89]), and targeted advertising or website information (2% each [2/89]).

Usability indicators referenced include website analytics (25% [22/89]), experts' evaluation (21% [19/89]), users' impact stories (16% [14/89]), user ratings (14% [12/89]), citations/references/mentions (9% [8/89]), and URL links (e.g. external sites that link to or embed dashboards; 2% [2/89]). Usability information was not provided for 47% of case studies included in the review [42/89]. Indicators of usefulness (e.g. impact on user knowledge, perceptions, decisions, or actions) mentioned in case studies include expectations regarding public health impact (19% [17/89]), stakeholder feedback or use (18% [16/89]), user engagement metrics (16% [14/89]), citations or references to dashboard in academic publications (14% [12/89]), and anecdotal evidence of association between policymakers' use of dashboard and policy actions (7% [6/89]). Information about impact indicators was not provided for 51% of the case studies reviewed (45/89).

Discussion

Data dashboards can be a useful tool for improving knowledge translation, efficient and timely dissemination of insights from research, and equitable access of diverse users to critical health-related information. They can also support evidence-informed decision-making by serving multiple functions (e.g. drawing attention and awareness to emerging challenges and monitoring change on existing ones, promoting more nuanced understanding of problems and potential solutions, facilitating goal setting, prioritizing, and sound allocation of resources, etc.) and can be valuable for data-focused collaborations. As public health data dashboards are poised to become more ubiquitous, it is imperative to proactively consider how they may be best designed to leverage public health data systems and meet the information needs of diverse audiences to support sound decisions regarding equitable and sustainable public health policies and practices [3, 10]. However, as evident from the findings of this scoping review, the scientific literature available to inform such efforts is considerably fragmented and lacking a standard, coherent focus regarding the goals, design, use, usefulness, and impact of these tools, as well as regarding factors (i.e., conditions, circumstances, and support mechanisms) that explain variations in their use and usefulness across users and applications [3, 8, 10, 11].

The rapid growth in public health data dashboard development in recent years – driven in part by the COVID-19 pandemic – may indicate that dashboard ecosystems are rapidly expanding along with technologies to support them, requiring conscientious approaches to dashboard design and applications, including improving on the adaptive or repurposing potential of these tools when public health priorities shift (as was the case for the COVID-19 dashboards). Despite this growth, our findings show that systematic and rigorously evaluated insights from the available literature regarding the optimal design, implementation, and improvement of public health dashboards are sparse and inconsistent, and therefore, insufficient to advancing the future development and successful application of these tools at scale as well as supporting rigorous evaluations of their efficacy and public health impact.

Most of the case studies included in the review were funded by the U.S. government, with grants being the common funding mechanism used to support the development of public health dashboards. The dashboards considered in the literature were also more commonly hosted on university websites and designed via scientific collaborations. While our sample of case studies may be admittedly biased towards dashboards developed in academia given that data were extracted from academic publications, legitimate questions nevertheless arise about the sustainability of such dashboard in light of familiar concerns about long term sustainability of these tools beyond classic project-based approaches to grant funded work [30]. Still, as key drivers of innovation [31], including in public health [32], universities are uniquely positioned with expertise and institutional capacity to lead dashboard development efforts. This tension point may represent a fruitful area for further investigation and discussion.

Our review and synthesis also point to limited application of data dashboards in public health, including in relation to health inequities. The findings show that public health dashboards are primarily used for epidemiological surveillance and monitoring of various health risks. From a health equity perspective, such use of dashboards necessarily invites public health focus on deficits or disparities across subpopulations and communities whereas dashboards can be an equally effective tool for mapping and tracking assets (e.g. available community resources that can pe tapped in public health emergencies). Similarly, dashboards can have an important role in supporting effective public health advocacy by regularly monitoring the health policymaking and public opinion arenas, but these types of applications are significantly less common based on the findings of the review. In terms of intended users, the dashboards in our study were more commonly geared towards public health decisionmakers and policymakers than other public health stakeholders such as the news

media, public health advocates, and the general public. While the data used in dashboards are predominantly collected and shared by federal and state public health agencies, with institutional capacity for data management, curation, and interpretation [33], the case studies reviewed suggest that local data is increasingly available for integration into public health dashboards, but it is not clear whether the quality and representativeness of local data are sufficient for supporting sound decisions [34], or whether the design of dashboards for federal and state policymakers used is equally responsive to local decision makers' knowledge needs and data use capacity. The finding that the practice of co-designing dashboards with users is rare, at least based on the cases reported in the literature on the topic, may raise concerns regarding the usability and usefulness of these tools to local public health decision makers.

Actionability Assessment

In addition to producing an updated, state-of-the-art review and analysis of public health data dashboards in the U.S., a primary motivation for conducting this scoping review was to clarify the meaning and significance of *actionability* as a property of effective public health data dashboards. Our findings distinguish among three principal conceptions of dashboard actionability. A common conception, popularized by Ivanković, et al. [22], understands actionability as the degree of match between purpose and use and associates it with functional design such that an actionable dashboard displays information clearly and efficiently, is intuitive to use, and is easily customizable to allow data exploration. Our analysis revealed that one-third of the case studies of dashboards reviewed (29/89) used functional design. Table 2 assesses the applicability of the actionability criteria proposed by Ivanković, et al. [22] to the case studies included in the review at the aggregate, recognizing that this scheme was developed to assess actual dashboards (as opposed to research reports on dashboards).

Table 2. Applicability of actionability criteria.

Actionability criterion	Scoping Review Findings
(1) Knowing and clearly stating the desired consumers of the information	Information about intended users was available for most of the case studies reviewed (83% [74//89]). Intended audiences identified were primarily public health decision makers, policymakers, and researchers, and to a lesser degree, practitioners, advocates, journalists, and the public.
(2) Selection and presentation of appropriate indicators	Virtually all case studies reviewed utilized indicators that were topic-relevant and aligned with the stated purpose of the dashboard. However, in only about half of all cases (50/89) appropriate indicators were determined after consulting intended users of a dashboard. Choice of indicators appears to be constrained by data availability.
(3) Clearly stating the sources of data and methods used to generate indicators	Sources and types of data were clearly noted in most case studies reviewed. However, there was less transparency regarding methods (not reported in 35% of case studies [31/89], software used (not reported in 28% of cases [25/89]), and collaborators, if any (not reported in 36% of cases [32/89]). There was no reference in the case studies reviewed to the inclusion of disclaimers regarding data limitations, although it is possible that disclaimers were included in some or most cases.

(4) Demonstrating variation over time and linking changes to public health interventions	About 40% of case studies reviewed (36/89) included visualization of trends in indicators, and 34% (34/89) allowed for temporal customization of data. None were linked to the effect of a public health intervention, although about 22% (20/89) of cases involved dashboards capable of extrapolating predictions of future trends. Still, this criterion does not universally apply to all dashboards given variations in purpose and type of data used.
(5) Providing as high a spatial resolution as possible to enable consumers to evaluate local risk	Most dashboards represented in the case studies reviewed (70% [62/89]) had a degree of data granularity extending to the local level. Still, this criterion does not universally apply to all dashboards given variations in purpose and the scope and quality of local data available.
(6) Disaggregating data to population subgroups to further enable evaluation of risk	About 27% of the case studies of dashboards reviewed (24/89) allowed for data disaggregation by demographics, 23.5% (21/89) for disaggregation by socioeconomics, and 8% (7/89) for disaggregation based on health insurance status. However, this particular affordance of public health dashboards is likely more common. At the same time, only 11% of the cases of dashboards reviewed (10/89) utilized data specific to a particular subgroup, which may indicate inadequate representation of minority and other vulnerable groups that are underrepresented in general population data.
(7) Providing narrative information to enhance interpretation of the data by the consumer	The findings of the scoping review do not reveal a standard approach to the inclusion of narrative information to aid interpretation. Such information was rarely included in the case studies reviewed, and most (75% [67/89]) did not include any information pertaining to dissemination to users.

Several valuable insights emerge from this exercise. First, dashboard actionability critically depends on the availability of the “right data” - not simply in terms of quality, relevance, and timeliness but also degree of data granularity and adequate representation of both subpopulations and relevant indicators. The “right data” also has much to do with public health focus: most case studies of dashboards reviewed were designed for epidemiological or health services access or utilization surveillance; only a handful were intentionally designed to support other critical public health missions such as health education and prevention, health policy advocacy, and improved access to health services. Thus, expending the types and diversity of data incorporated into dashboards is necessary for enhancing the actionability of these tools. Second, actionability is also a function of match to purpose and use, which varies depending on goal of data use (e.g. surveillance vs. analysis or prediction) and the range of questions that can be answered given the data layering and customization possibilities afforded by a dashboard. This dimension of actionability is acutely relevant for exploring or analyzing data in context: less than 15% of case studies of dashboards included in the review afforded users the opportunity to explore the relevance or significance of contextual factors such as social determinants of health. Third, use of dashboards can result in unintended or undesirable effects [3]. This may be due to bias in the data used for creating a dashboard [35], bias associated with the presentation of data [36], or bias (whether intentional or unintentional) that affects the correct interpretation or proper use of insights drawn from data. Actionability, therefore, requires acknowledgement of any actual and potential limitations or sources of bias that may influence dashboard use. This necessarily means going beyond mere transparency

regarding data sources, methods, and funding to introducing, as a matter of standard practice, built-in guardrails against uninformed or improper use of dashboards in the form of alerts or cautions, disclaimers, and perhaps even recommendations or guidelines regarding acceptable use.

A second and equally common conception of actionability emerging from the case studies of dashboards reviewed (32% of case studies [28/89]) is behavioral or user-centered design. This conception primarily understands dashboard actionability as a function of both usability and usefulness: dashboards can support evidence-informed decisions and actions only if they are usable (i.e. sufficiently easy and intuitive for users to navigate, interact with, and customize data visualizations) and useful in terms of being responsive to users' information needs and generating valuable insights for guiding users' understanding, reflection, decisions, and ultimately actions. Of the two, usefulness appears to be most relevant to operationalizing actionability since usability is closely associated with a user's technical and data analytical literacy and therefore may be considered a necessary but insufficient determinant of usefulness. However, our findings suggest that use and usability evaluations — whether via use of website analytics (25% of all case studies reviewed [22/89]), experts' evaluation (21% [19/89]), and user ratings (14% [12/89]) — are more common than evaluations of usefulness. Moreover, we found no evidence of systematic or rigorous evaluations of usefulness across the case studies of dashboards included in the scoping review. When an effort is made to assess usefulness, it is typically based on anecdotal user feedback (18% of all case studies reviewed [16/89]), user engagement metrics derived from website analytics (16% [14/89]), or distal indicators such as citations or references to dashboard in academic publications (14% [12/89]). In this regard, we note that virtually none of the case studies of dashboard included in the review included an explicit theory of action that causally links dashboard use and usability to usefulness and impact of use, including the underlying mechanism that explains how use relates to outcomes (e.g. drawing attention, facilitating learning and comprehension, persuading, guiding choice among alternative actions, etc.).

Whereas user-centered design is frequently referenced in these case studies as the framework guiding the development of usable and useful dashboards, the development of these tools appears to be based mostly on dashboard developers' expectations regarding how users *should* interact, experience, and be influenced by using a dashboard than robust and thoughtful engagement with potential users and their expectations and needs. The fact that case studies that referenced utilizing a co-design process to develop a dashboard were significantly fewer than case studies in which a dashboard was developed with no or minimal input from intended users (26% compared to 44% of all case studies, respectively), and that when collaborations were referenced, they most frequently involved scientific collaborations (51% of all cases [45/89]) and less frequently collaborations with users (17% of all cases [15/89]), appears to support this conclusion.

A third, less common conception of actionability that emerged from the scoping review (32% of case studies [28/89]) is focused on the degree of match between the insights that can be drawn from using a dashboard and the nature of the decision facing users. This conception of actionability is based on the recognition that use of dashboards is often motivated by organizational goals and therefore ought to vary depending on whether strategic, tactical, or operational decisions are involved [21]. Thus, dashboards primarily designed for surveillance and monitoring (representing most of the case studies reviewed) can support operational decisions; dashboards that enable users to probe and analyze causes of health disparities or compare the efficacy of different intervention approaches can support tactical decisions; and dashboards that offer predictions of future trends (about 12% of case studies of dashboards included in the review) or present data in context (e.g. social determinants of health; about 30% of case studies reviewed) can support strategic decisions regarding health policy and investments. This conception of actionability appears to be the least developed in the literature but

may deserve greater attention from dashboard developers and researchers alike.

In summary, actionability assessment as applied to dashboards is more complex and multifaceted than portrayed in the literature on the topic. Among others, actionability is a function of user factors (capacity, needs, motivations, etc.); characteristics of available data (quality, completeness, relevance, timeliness, granularity, etc.); purpose (surveillance/monitoring, enlightenment, diagnosis, prediction/prognosis, prescription for action, etc.); decisional goals (e.g. strategic, tactical, or operational); desired impact (e.g. on policy, practice, system change, public education, etc.); and design elements (usability, functionality, interactivity, customization, adaptability, etc.). It also requires consistent and informed use of dashboards and therefore is likely associated with quality of dissemination efforts (that is, how users find out about the availability and value of using a dashboard), guidance regarding appropriate (and ethical) use, thoughtful integration with existing systems and users' professional routines, and sustained sources of funding for technical support, maintenance, and continued improvement. Given this complexity, it is difficult to envision a standard set of metrics or indicators for studying and assessing actionability across applications and users of dashboards. A more productive path forward is to move away from a conception of actionability as a trait or property of usable and useful dashboards in favor of a more dynamic conception that understands actionability as a function of the iterative process used to conceive, design, deploy, evaluate, improve, and sustain dashboards that users find usable and useful given their goals, knowledge needs, and capacity.

Limitations and Future Work

The scoping review methodology employed in this study has several potential limitations. First, whereas we took multiple steps to ensure the rigor of our literature search and screening strategy, it is still possible that some relevant studies that met the study's inclusion criteria were overlooked, including studies published since our search was concluded in mid-2023. However, by opting for a procedure designed to maximize recall (coverage) at the expense of precision (specificity), we were able to mitigate any potential bias due to omission of relevant studies. Second, and related to scope, the studies included in this scoping review were limited to public health data dashboards in the U.S. whereas our search strategy identified a nontrivial number of relevant studies involving public health dashboards developed in other countries. Regions and countries around the world vary in terms of available public health data infrastructure, health systems, and public health conditions and priorities, such international sample of case studies, and while not directly comparable, may produce additional valuable insights and therefore deserve similar attention. Accordingly, we plan to conduct a separate, complementary scoping review of these additional case studies, using the same procedure and methodology implemented in this study, and compare the findings to the ones reported here, noting any similarities and differences between the two samples. Third, case studies of public health data dashboards that are available from the academic literature on this topic may overrepresent a particular type or subpopulation of dashboards (e.g. dashboards developed and evaluated by university researchers) and therefore underrepresent the actual diversity of dashboard applications in public health, which may potentially bias our findings and conclusions. At the same time, our findings and conclusions are largely congruent with those reported by previous similar literature syntheses [2,4,12-14]. In addition, the next phase of our project, which involves coding and analysis of a probability sample of U.S. federal and state public health data dashboards, will permit us to assess the degree and type of bias, if any, in the literature based on the findings of this scoping review. Lastly, because the studies included in this scoping review vary considerably in the type and depth of the information provided, our data extraction and analysis, which focuses on detecting and synthesizing patterns of findings, may not be sufficiently robust to derive practical recommendations regarding the optimal design of actionable public health data dashboards; however, we believe this research contributes to advancing additional theory and research on this topic.

Conclusions

Public health data dashboards have significant potential to support evidence-informed policy and practice decisions if they are actionable. The findings of the scoping review reveal a rather fragmented body of scholarship on this topic which lacks a coherent and systematic focus on the various functions, design elements, causal mechanisms, conditions, and range of outcomes of dashboard use and their relationship with actionability across applications and diverse user groups. Notably absent from current scholarships are explicit theories of action that identify major factors (user-, design-, goal-, and context-related) that facilitate or impede informed use of these tools and explicate the mechanisms that link use with outcomes (e.g. users' knowledge, sensemaking, reflection, decisions, and actions) and from there to impact practice or policy. Also notably missing are rigorously designed empirical studies that go beyond usability assessments to assess usefulness of dashboards as key dimension of actionability as well as studies that tease out the relative advantages and disadvantages of different dashboard design philosophies and processes and produce practical recommendations. There is a significant opportunity for future research to advance both scholarship and practice regarding the design, deployment, and sustainability of actionable dashboards by addressing these existing gaps.

Acknowledgements

This scoping review was funded by the Robert Wood Johnson Foundation. The views expressed here do not necessarily reflect the views of the Foundation, which had no role in the study design, decision to publish, or drafting of the manuscript. GS and IY contributed equally to the study concept and design, literature search strategy, screening and analysis of the case studies included in the review and drafting of the manuscript. MK contributed to pretesting and refinement of the literature search strategy, the initial development of the data extraction instrument, and to screening and analysis of the case studies. All authors read and approved the paper for submission.

Conflicts of Interest

None declared.

References

1. Gardner L, Ratcliff J, Dong E, Katz A. A need for open public data standards and sharing in light of COVID-19. The Lancet Infectious Diseases. 2021;21(4):e80. doi: 10.1016/S1473-3099(20)30635-6.
2. Khodaveisi T, Dehdarirad H, Bouraghi H, Mohammadpour A, Sajadi F, Hosseiniravandi M. Characteristics and specifications of dashboards developed for the COVID-19 pandemic: a scoping review. J Public Health-Heid. 2023 Feb 2. PMID: WOS:000925686900001. doi: 10.1007/s10389-023-01838-z.
3. Dasgupta N, Kapadia F. The Future of the Public Health Data Dashboard. American Journal of Public Health. 2022;112(6):886-8. PMID: 35613427. doi: 10.2105/ajph.2022.306871.
4. Schulze A, Brand F, Geppert J, Boel GF. Digital dashboards visualizing public health data: a systematic review. Frontiers in Public Health. 2023 May 4;11. PMID: WOS:000991015600001. doi: ARTN 999958
10.3389/fpubh.2023.999958.
5. Few S. Information dashboard design: The effective visual communication of data: O'reilly Sebastopol, CA; 2006.
6. Han Q, Nesi P, Pantaleo G, Paoli I, editors. Smart City Dashboards: Design, Development, and Evaluation. - 2020 IEEE International Conference on Human-Machine Systems (ICHMS); 2020 2020.

7. Sarikaya A, Correll M, Bartram L, Tory M, Fisher D. What Do We Talk About When We Talk About Dashboards? 2019. p. 682-92.
8. Wu E, Villani J, Davis A, Fareed N, Harris DR, Huerta TR, et al. Community dashboards to support data-informed decision-making in the HEALing communities study. Drug Alcohol Depend. 2020 Dec 1;217:108331. PMID: 33070058. doi: 10.1016/j.drugalcdep.2020.108331.
9. D'Agostino EM, Feger BJ, Pinzon MF, Bailey R, Kibbe WA. Democratizing Research With Data Dashboards: Data Visualization and Support to Promote Community Partner Engagement. American Journal of Public Health. 2022 Nov;112:S850-S3. PMID: WOS:000909315200002. doi: 10.2105/Ajph.2022.307103.
10. Dixon BE, Dearth S, Duszynski TJ, Grannis SJ. Dashboards Are Trendy, Visible Components of Data Management in Public Health: Sustaining Their Use After the Pandemic Requires a Broader View. American Journal of Public Health. 2022;112(6):900-3. PMID: 35446601. doi: 10.2105/ajph.2022.306849.
11. Thorpe LE, Gourevitch MN. Data Dashboards for Advancing Health and Equity: Proving Their Promise? American Journal of Public Health. 2022;112(6):889-92. PMID: 35446603. doi: 10.2105/ajph.2022.306847.
12. Vahedi A, Moghaddasi H, Asadi F, Hosseini AS, Nazemi E. Applications, features and key indicators for the development of Covid-19 dashboards: A systematic review study. Informatics in Medicine Unlocked. 2022 2022/01/01/;30:100910. doi: https://doi.org/10.1016/j.imu.2022.100910.
13. Zhou BJ, Liang SW, Monahan KM, Singh GM, Simpson RB, Reedy J, et al. Food and Nutrition Systems Dashboards: A Systematic Review. Adv Nutr. 2022 Jun 1;13(3):748-57. PMID: WOS:000786100000001. doi: 10.1093/advances/nmac022.
14. Carroll LN, Au AP, Detwiler LT, Fu TC, Painter IS, Abernethy NF. Visualization and analytics tools for infectious disease epidemiology: A systematic review. Journal of Biomedical Informatics. 2014 Oct;51:287-98. PMID: WOS:000343362800028. doi: 10.1016/j.jbi.2014.04.006.
15. Stieb DM, Huang A, Hocking R, Grouse DL, Osornio-Vargas AR, Villeneuve PJ. Using maps to communicate environmental exposures and health risks: Review and best-practice recommendations. Environ Res. 2019 Sep;176. PMID: WOS:000483410200060. doi: ARTN 108518 10.1016/j.envres.2019.05.049.
16. Narayan KA, Nayak MSDP. Need for interactive data visualization in public health practice: Examples from India. Int J Preventive Med. 2021 Jan-Dec;12(1). PMID: WOS:000625221500016. doi: 10.4103/ijpvm.IJPVM_171_20.
17. Barbazza E, Ivankovic D. What makes COVID-19 dashboards actionable? Lessons learned from international and country specific studies of COVID-19 dashboards and with dashboard developers in the WHO European Region...14th European Public Health Conference (Virtual), Public health futures in a changing world, November 10-12, 2021. European journal of public health. 2021 10/02;31:iii184.
18. Bos CV, Jansen T, Klazinga SN, Kringos SD. Development and Actionability of the Dutch COVID-19 Dashboard: Descriptive Assessment and Expert Appraisal Study. JMIR Public Health Surveill. 2021 10/12;7(10):e31161.
19. Mach KJ, Lemos MC, Meadow AM, Wyborn C, Klenk N, Arnott JC, et al. Actionable knowledge and the art of engagement. Curr Opin Env Sust. 2020 Feb;42:30-7. PMID: WOS:000523572800006. doi: 10.1016/j.cosust.2020.01.002.
20. Sorapure M. User Perceptions of Actionability in Data Dashboards. Journal of Business and Technical Communication. 2023;37(3):253-80. doi: 10.1177/10506519231161611.
21. Verhulsdonck G, Shah V. Making Actionable Metrics “Actionable”: The Role of Affordances and Behavioral Design in Data Dashboards. Journal of Business and Technical Communication. 2022;36(1):114-9. doi: 10.1177/10506519211044502.
22. Ivanković D, Barbazza E, Bos V, Brito Fernandes Ó, Jamieson Gilmore K, Jansen T, et al. Features Constituting Actionable COVID-19 Dashboards: Descriptive Assessment and Expert

Appraisal of 158 Public Web-Based COVID-19 Dashboards. J Med Internet Res. 2021 /2/24;23(2):e25682.
23. Matheus R, Janssen M, Maheshwari D. Data science empowering the public: Data-driven dashboards for transparent and accountable decision-making in smart cities. Government Information Quarterly. 2020 July 2020;37(3):101284. doi: https://doi-org.proxy.libraries.rutgers.edu/10.1016/j.giq.2018.01.006.
24. Peters MDJ, Marnie C, Colquhoun H, Garritty CM, Hempel S, Horsley T, et al. Scoping reviews: reinforcing and advancing the methodology and application. Systematic Reviews. 2021 Oct 8;10(1). PMID: WOS:000705203000004. doi: ARTN 263
10.1186/s13643-021-01821-3.
25. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. Ann Intern Med. 2018 Oct 2;169(7):467-+. PMID: WOS:000446042400006. doi: 10.7326/M18-0850.
26. Yanovitzky I, Stahlman G, Quow J, Ackerman M, Perry Y, Kim M. National Public Health Dashboards: Protocol for a Scoping Review JMIR Res Protoc 2024;13:e52843
doi: 10.2196/5284327.
27. Salvador-Olivan JA, Marco-Cuenca G, Arquero-Aviles R. Errors in search strategies used in systematic reviews and their effects on information retrieval. J Med Libr Assoc. 2019 Apr;107(2):210-21. PMID: WOS:000465501100011. doi: 10.5195/jmla.2019.567.
28. Stryker JE, Wray RJ, Hornik RC, Yanovitzky I. Validation of Database Search Terms for Content Analysis: The Case of Cancer News Coverage. Journalism & Mass Communication Quarterly. 2006;83(2):413-30. doi: 10.1177/107769900608300212.
29 Gusenbauer M, Haddaway NR. Which academic search systems are suitable for systematic reviews or meta-analyses? Evaluating retrieval qualities of Google Scholar, PubMed, and 26 other resources. Res Synth Methods. 2020 Mar;11(2):181-217. PMID: WOS:000509659900001. doi: 10.1002/jrsm.1378.
29. Hayes AF, Krippendorff K. Answering the Call for a Standard Reliability Measure for Coding Data. Communication Methods and Measures. 2007 2007/04/01;1(1):77-89. doi: 10.1080/19312450709336664.
30. Scheirer MA, Dearing JW. An Agenda for Research on the Sustainability of Public Health Programs. *Am J Public Health*. 2011;101(11):2059-2067. doi:10.2105/AJPH.2011.300193
31. Etzkowitz H, Leydesdorff L. The dynamics of innovation: from National Systems and “Mode 2” to a Triple Helix of university–industry–government relations. *Research Policy*. 2000;29(2):109-123. doi:10.1016/S0048-7333(99)00055-4
32. Bachmann P, Frutos-Bencze D. R&D and innovation efforts during the COVID-19 pandemic: The role of universities. *Journal of Innovation & Knowledge*. 2022;7(4):100238. doi:10.1016/j.jik.2022.100238
33. Shankar K, Jeng W, Thomer A, Weber N, Yoon A. Data curation as collective action during COVID-19. *Journal of the Association for Information Science and Technology*. 2021;72(3):280-284. doi:10.1002/asi.24406
34. Loukissas YA. Taking Big Data apart: local readings of composite media collections. *Information, Communication & Society*. 2017;20(5):651-664. doi:10.1080/1369118X.2016.1211722
35. Viswanath K, McCloud RF, Lee EWJ, Bekalu MA. Measuring What Matters: Data Absenteeism, Science Communication, and the Perpetuation of Inequities. *The ANNALS of the American Academy of Political and Social Science*. 2022;700(1):208-219. doi:10.1177/00027162221093268
36. Okan Y, Garcia-Retamero R, Cokely ET, Maldonado A. Biasing and debiasing health decisions with bar graphs: Costs and benefits of graph literacy. *Quarterly Journal of*

Experimental Psychology. 2018;71(12):2506-2519. doi:10.1177/1747021817744546

Supplementary Files

Multimedia Appendixes

Flow diagram of paper screening and selection process.
URL: http://asset.jmir.pub/assets/61051da04f3f6d569c8ee3097da0b1e8.docx

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist.
URL: http://asset.jmir.pub/assets/1e1b90822b08364d48d7db0f9565d3f7.docx

List and characteristics of case studies included in the scoping review.
URL: http://asset.jmir.pub/assets/dbe71f40948ddfb4c65c3b27c6b936b5.docx