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REVIEW

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Precision public health after Covid-19: a scoping review

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Abstract

"Precision public health" (PPH) emerged in 2015 as a charismatic vision to revolutionize traditional public health with data-driven solutions to the world's most challenging public health problems. A central goal of PPH is to use population-level data to improve health equity by targeting geographically localized at-risk populations. For this article, we conducted a scoping review to investigate whether and how PPH approaches were used for Covid-19 pandemic response and how they incorporated health equity goals in their approaches. We found that during the Covid-19 pandemic, discussions of PPH in the academic literature mostly focused on potential future implementation of PPH rather than on-the-ground Covid-19 pandemic response. In the few articles that described a research project and/or public health intervention at the intersection of PPH and Covid-19, researchers articulated PPH together with three sets of Covid-19 era public health practices: 1) vulnerability indexes; 2) near real-time surveillance; 3) pathogen sequencing. In each of these articulations, the most common method for achieving health equity was using epidemiological surveillance data to create risk stratification to direct resources to the most vulnerable. As these new articulations are tentative and have not yet become common in public health literature and policy, the article ends with a critical call to interrogate which versions of health equity are enacted and foreclosed in data-driven approaches to public health and how PPH can best serve vulnerable populations.

Introduction

"Precision public health" (PPH) emerged in 2015 as a charismatic vision to revolutionize traditional public health with data-driven solutions to the world's most challenging public health problems—from emergencies like novel pandemics and extreme weather events to longstanding and endemic health challenges such as HIV/AIDS and maternal and infant mortality. Taking inspiration from "precision medicine"—previously "personalized medicine"—"precision public health" promised to leverage large data sets, population genomics, unconventional data sources, and near real-time surveillance to efficiently and effectively target public health problems in populations. Championed by high-profile public health figures such as Muin Khoury (founding Director of the Office of Public Health Genomics, CDC) and Sue Desmond-Hellman (former CEO of the Bill & Melinda Gates Foundation) PPH gained significant public attention in 2016 with a high-profile Precision Public Health Summit organized by the University of California, San Francisco, the Obama White House, and the Gates Foundation. A central goal of PPH, from the beginning, has been to use population-level data to design interventions that address health equity in geographically localized at-risk populations.

In our previous article, "The Imaginary of Precision Public Health," [1] we analyzed precision public health as a sociotechnical imaginary with a focus on the role of health equity in PPH proposals. Science and Technology Studies (STS) scholar Sheila Jasanoff defines sociotechnical imaginaries as "collectively held and performed visions of desirable futures…animated by shared understandings of forms of social life and social order attainable

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through, and supportive of, advances in science and technology" [2]. STS scholars use the term "sociotechnical imaginaries" to draw attention to the ways that aspirations for the future of science, technology, and medicine shape research agendas and investments in the present. In "The Imaginary of Precision Public Health," we used the concept of "sociotechnical imaginaries" to ask how the PPH vision for a data-driven *future* was shaping public health in the *present* and considered whether PPH offered the best roadmap for addressing health disparities in populations, asking whether this approach could meaningfully reduce unequal burdens of morbidity and mortality. Ultimately, we urged caution in adopting PPH for health equity aims, because the targeted solutions of PPH do not adequately address the upstream social determinants of health that are the root cause of health disparities worldwide. The charisma of PPH, we argued, has the potential to take media and policy attention, as well as funding, infrastructure, and resources, away from more tried-and-true public health strategies and grassroots community efforts.

In this article, we revisit the promises of PPH in light of the Covid-19 pandemic, where public health actors and approaches came up against real-world challenges leading to varied policies and inconsistent outcomes [3] —a reality that was in stark contrast to the efficient, equitable, data-driven futures imagined by the popularizers of PPH. To date there has only been one Portuguese-language literature review on precision medicine and Covid-19 published early in the pandemic [4]; there has not been any systematic investigation into how PPH was applied in Covid-19 public health efforts. To address this gap, we conducted a scoping literature review of peer-reviewed articles, edited volume chapters, commentary articles, and institutional and NGO websites that discuss PPH in the context of Covid-19. The goal was to investigate whether the imaginary of PPH has remained constant or whether this approach has adapted to the shifting realities of this ongoing public health emergency. We asked: How have public health efforts to address Covid-19 been articulated with the imaginary of PPH? Were any precision public health projects implemented in the global public health efforts around Covid-19, or are the promises of PPH still largely unrealized? After eight years of investment, we seek to account for what has happened to PPH when it encountered the reality of a global pandemic that exacerbated existing health inequities locally and worldwide.

Methods

This article is based on a scoping review [5] of articles that discuss PPH in the context of SARS-CoV-2 and the Covid-19 pandemic. We began our review with a Pubmed search for peer-reviewed articles that contained the terms "Covid-19" and "Precision Public Health" in the title, abstract, and/or keywords from January 2020 to February 2024. We excluded articles that made only incidental mention of Covid-19 or Precision Public Health in order to focus on articles that explicitly discuss PPH approaches to the Covid-19 pandemic. Through this process, we included 13 peer-reviewed articles and added an additional 8 commentary articles and 4 edited volume chapters to the sample based on a hand-search of Google Scholar. Since commentary articles often do not have abstracts, hand searching was necessary to find relevant commentary articles.

Then, following the lead of the articles, we searched the websites of major institutional actors mentioned as central to national and global public health provision in the context of Covid-19 to see how and in what ways PPH as a concept and a set of practices was taken up, and connected with the pandemic response. These web searches followed the same methodological approach, looking for conjoined terms "Covid-19" or "SARS-CoV-2"and "Precision Public Health" in titles, descriptions, or keyword searching, downloading any research reports and pulling website content.

Together the articles, reports, and website content were analyzed thematically focusing on the definitional work of PPH, its approaches and goals, and the role of health equity in PPH Covid-19 response. We then applied a modified social worlds analysis [6] paying attention to social worlds, defined as groups of various sizes that share an interest in emergency response to SARS-CoV-2 and the Covid-19 pandemic. We analyzed the ways technologies and practices, from health, global health, informatics, genomics, and other biomedical fields, were brought into, and *articulated* as part of the imaginary of PPH.

Theory: articulating PPH

In this article, we look at how PPH has been defined by researchers and public health actors during the Covid-19 pandemic and identify three Covid-era public health practices that have been *articulated* with the imaginary of PPH in public health research: 1) vulnerability indexes, 2) near real-time public health surveillance, and 3) pathogen sequencing. Influential sociologist Stuart Hall defined articulation as a historically contingent link between two or more disparate elements or practices that must be constantly renewed or the connection can disappear [7]. Rather than assuming that social formations are natural or inevitable, Hall suggests that we investigate "the political-cultural work (practice[s]) that [goes] into making and sustaining specific articulations" [8]. When researchers call their projects "precision public health"

they perform the political-cultural work of connecting their research to a desirable high-tech future for public health, potentially increasing their research profile and opening up opportunities for funding. In doing so, they strengthen the imaginary of precision public health by providing evidence of the efficacy of PPH approaches to Covid-19.

Here we describe how vulnerability indexes, near real-time public health surveillance, and pathogen sequencing have been articulated with PPH and identify the visions of health equity they present. As Hall emphasized, these articulations are not inevitable or permanent, but are historically contingent [9] and may become strengthened, eroded, or re-articulated as public health frameworks and priorities change. As you will see below, these novel articulations between Covid-era public health practices and PPH are new and tentative. It remains to be seen whether they will be strengthened to become lasting frameworks in public health or whether these practices will be articulated with another yet-to-be-realized paradigm for public health. However, given the power of the precision imaginary to drive investment in the present, it is important to continue to interrogate these charismatic proposals for the future of public health.

Findings: the definition of precision public health

Definitional stability of PPH

In the literature on PPH and Covid-19, we found that the definition of PPH has remained mostly stable from its introduction in 2015 through February 2024 [1]. Although still broadly defined and somewhat nebulous, PPH during the Covid-19 pandemic is defined as data-driven, up-to-the-minute public health interventions that target public health problems in populations, often delimited by geography and population characteristics. For example, Rasmussen et al. write:

> *Precision public health is an emerging discipline that uses extensive population-specific data to provide the right intervention to the right population at the right time. Precision public health uses data from traditional and emerging sources to target interventions for populations by person, place, and time, in part with a focus on reducing health disparities [10].*

Reflecting its origins in precision medicine, definitions of PPH during Covid-19 continued to advocate for the integration of genomic knowledge and technologies into population health data collection and intervention efforts. This is evidenced in the CDC's "COVID-19 Genomics and Precision Health Database" (COVID-19 GPH), where 72% of the searchable articles are focused on pathogen and human genomics [11].

Pathogen sequencing and phylogenetic analysis were of particular importance, with researchers tracking new variants of concern as they spread globally in real-time [12–14]. Many of these definitions retain a strong health equity component, with an emphasis on delivering public health interventions to the most vulnerable. Macharia et al. write:

> *Fighting the COVID-19 pandemic calls for precision public health reflecting our improved understanding of who is most vulnerable and what makes them more vulnerable, where the disease is spreading or likely to spread fastest, and where current interventions may not work as intended [15].*

In this way, population data from traditional surveillance tools in public health such as morbidity rates, are coupled with genome sequencing data, as well as the addition of non-traditional sources such as Google trends data [16] are used to locate vulnerable populations who can be targeted for the distribution of information and resources, such as PPE and vaccines [17]. While many of the details are specific to the Covid-19 pandemic (e.g. the importance of pathogen sequencing and vaccine distribution), the overall definition of PPH has remained consistent.

PPH remains anticipatory

In the literature on PPH and Covid-19, we found that PPH most often remained in the realm of an anticipated future, a new paradigm for public health that was still "just around the corner; coming soon." [18] Yet, in light of the public health shortcomings during the Covid-19 pandemic, PPH provided a hopeful, more desirable vision of what public health could and should look like. In these articles, PPH is often figured as the "right tool for the job," [19, 20] especially for key promoters of the paradigm. For these actors, PPH offers the promise of a smarter, more responsive public health that could efficiently target resources to those most in need. Zhou et al. present an account of what proponents of PPH argued it could offer during the Covid-19 pandemic:

> *PPH approaches using community-level data on infections from robust testing, Geographic Information Systems (GIS), spatial mapping, and digital data could be used to locate COVID-19 "hot spots" with higher risks of transmission or severe responses…This kind of data could help local officials make public health decisions, such as targeting high-risk communities for surveillance and messaging on the spread of COVID-19 and when and how to seek medical attention. Additionally, prevention messages could be tailored to communities in cultur-*

ally appropriate ways [21].

Authors imagine that PPH could create more localized and granular approaches to public health measures such as school closures, cancellation of mass gatherings, recommendations to work from home, mask mandates, and stay-at-home orders [10]. Rather than issuing blanket public health orders on the federal, state, or municipal level, PPH would be able to use near real-time data to target, assess, and adjust interventions on a more granular and hyper-local scale [22]. Such approaches would complement and potentially work alongside public health grassroots and community efforts to prevent Covid exposures, and increased morbidity and mortality rates. While epidemiological data was used extensively to guide public health policy during the pandemic, PPH offered the vision of an idealized technocratic public health regime without wasted resources, unnecessary suffering or scientific uncertainty. Due to the perceived need for evidence-based public health policy, some authors argued: "there is no better time to turn public health into PPH than now." [14].

Interrogating the limits of PPH

Amid sweeping calls for a PPH revolution, some articles take a more cautious approach, asking, "Is precision public health the future — or a contradiction?" [23] or "Is precision medicine relevant in the age of Covid-19?" [21] Both of these commentary articles include the perspectives of social scientists and urge some degree of caution in investing in PPH. They argue that it is important that PPH not "divert attention from less glamorous, but more effective, public health measures" [21] and, significantly, that public health must commit to addressing the root causes of health disparities, not only their outcomes. Zhou et al. et al. argue that it is important that PPH interventions do not "lose sight of the broader social determinants that shape differential risk and responses to COVID-19." [21] Dr. Sandro Galea, a prominent critic of PPH, argues that, in the U.S. context, better social policies such as access to quality affordable housing and mandating paid sick leave might do more to curb a pandemic than targeted interventions [23]. The efficacy of these kinds of policies is supported by data on the occupational stratification of Covid-19 morbidity and mortality in the U.S. that shows how high-exposure occupations (i.e. "essential workers") were disproportionately comprised of racial and ethnic minorities [24–26].

In the articles that met the inclusion criteria for this study, there are a greater number of articles that focus on the biases in current data collection infrastructures that will be carried forward with PPH than in our initial study published in 2019 [1]. Authors [27–29] argue that for marginalized populations, such as racial and ethnic minorities and American Indian/Alaska Natives, insufficient or defective data collection can undermine the health equity goals of PPH. Furthermore, they argue that data collection by itself is not enough; care must be taken when public health data is interpreted and turned into policy recommendations: "Data equity requires `sense making` by public health agencies in which numbers are interpreted in the context of the lives, risks, and stories of those whom the data are meant to help" [28]. In order to create a more systematic approach to health equity in PPH, Allen et al. offer a list of best practices for applying an anti-racist lens to PPH initiatives from stakeholder engagement to the development of evidence-based interventions to evaluation—moving the discussion of bias in PPH from critique to actionable recommendations [29].

Findings: new articulations

While the majority of the articles and websites still frame PPH as future-oriented, these coexisted with new articulations of PPH and public health practices in the present: examples of original research that connected the established definitions of PPH with the public health practices used in Covid-19 pandemic response. In the following section we show how vulnerability indexes, near real-time surveillance, and pathogen sequencing have been articulated together with the precision imaginary by researchers and public health actors (Table 1). By drawing these connections, researchers contribute to the perception that PPH is effective approach to public health during the pandemic capable of addressing health disparities. For each of the new articulations below, we discuss what version of health equity is being enacted (Table 2) and what alternative visions for health equity are foreclosed.

Table 1 New Articulations

PPH and Vulnerability Indexes	Macharia et al 2020 [15], Moore et al 2023 [31], Mays et al 2022 [28]
PPH and Near Real-Time Surveillance	Arnold 2022 [23], Kappus-Kron et al 2024 [32], De La Cerda et al 2023 [33]
PPH and Pathogen Sequencing	Maison et al 2022 [13], Arriaga-Canon 2022 [14], Rich et al 2023 [12]

Table 2 New Articulations of PPH and Health Equity: 3 Case Studies

Vulnerability Indexes: Macharia et al 2020 [15]	Definition of PPH: "Fighting the COVID-19 pandemic calls for precision public health reflecting our improved understanding of who is most vulnerable and what makes them more vulnerable, where the disease is spreading or likely to spread fastest, and where current interventions may not work as intended."
	Path to Health Equity: "The [vulnerability] indices…presents tools that can be used by the Kenyan government and stakeholders to [create] a better plan by prioritising subcounties that are moderate to highly vulnerable."
Near Real-Time Surveillance: De La Cerda et al 2023 [33]	Definition of PPH: "What we present here is a case for precision public health that uses new technologies to improve local public health efforts by generating tailored and spatially targeted interventions."
	Path to Health Equity: "Our experiences and findings advocate not only for strong agency-academic collaborations but also for improved, granular population surveillance data sources on a national scale that can be leveraged to target interventions and deliver the correct intervention to the high-risk population in a timely manner."
Pathogen Sequencing: Maison et al 2022 [13]	Definition of PPH: "Precision public health genomics is a public health policy tool to track the spread of viruses…For precision public health genomics to be effective during the COVID-19 pandemic, high-throughput sequencing and high-speed, low-cost sequence data analysis, and robust phylogenetics are necessary."
	Path to Health Equity: "The conclusion from defining the origin of VOC in Hawai'i is that California is the primary source of VOC circulating in Hawai'i. Additional screening and quarantining of the travelers from California while vacationing in Hawai'i will protect the local population from evasive SARS-CoV-2 VOC."

New articulation 1: vulnerability indexes

The practice of creating social vulnerability indexes for U.S. public health emergencies began post-Hurricane Katrina and has grown in popularity during Covid-19 pandemic [30]. Vulnerability indexes have become popular tools for spatially mapping populations most at-risk from extreme weather events, pandemics, and other large-scale emergencies in the fields of disaster planning, environmental science, and public health [30]. The purpose of vulnerability indexes is to target prevention efforts and to direct the distribution of resources to the most vulnerable during emergencies. As vulnerability indexes became a common public health tool deployed during the Covid-19 pandemic to assess risk, some researchers articulated vulnerability indexes with the imaginary of PPH [15, 28, 31]. In "A vulnerability index for COVID-19: spatial analysis at the subnational level in Kenya" (2020), Macharia et al. use available public health data to create a social vulnerability index and an epidemiological vulnerability index mapped onto subcounties in Kenya [15]. Social vulnerability was calculated through a combination of variables designed to measure socioeconomic deprivation, population characteristics, and access to healthcare; epidemiological vulnerability was measured by the incidence of comorbidities such as HIV and non-communicable diseases. By creating and combining these two indexes, the authors aimed to contribute to a more precise approach to early pandemic response in Kenya. They encourage the Kenyan government and other public health stakeholders to use these vulnerability indices to prioritize moderately and highly vulnerable subcounties in their public health response.

In this article, Macharia et al. [15] articulate Covid-era vulnerability indexes with the PPH vision of using spatial mapping to identify and target the most vulnerable for public health interventions and the distribution of public health resources. Data-driven risk stratification is the means by which health equity is achieved in this PPH framing. By identifying geographical locations where people are disproportionally exposed to Covid-19 and experience more severe disease outcomes, Macharia et al. seek to mitigate the most acute effects of the pandemic by targeting the populations who are likely to be most impacted. In line with our previous analysis, [1] this version of health equity requires investment in data collection and infrastructure, rather than investment in addressing the social determinants of health—e.g. access to clean water, food, and healthcare. They conclude by arguing that Africa should invest in data collection in order to increase preparedness for emerging and endemic public health emergencies such as Covid-19, malaria, and Ebola virus disease. Here we see how precision as a socio-technical imaginary is called upon to shape investment in the present, even if it has not yet been fully realized.

New articulation 2: near real-time surveillance

Since 2015, near real-time public health surveillance has been central to the imaginary of PPH. During the Covid-19 pandemic, many cities around the world implemented up-to-the-minute Covid-19 data dashboards. San Francisco, for example, published data on daily Covid

infection and mortality rates by neighborhood, number of Covid hospitalizations, infection and mortality rates by population characteristics, and data related to high-risk settings such as single-room occupancies and skilled nursing facilities. Commentary articles, especially, connected these municipal data collection efforts with the goals of PPH. For example, the *Nature* feature "Spurred by Covid, Public Health Gets Precise," begins with the story of a mobile testing lab in New York City that used SaTScan—an open-source data analysis tool—to identify the most effective location to dispatch a Covid-19 testing van [23].

Frustrated with blanket public health mandates, researchers turned to PPH for more granular and immediate data collection tools referred to as "nowcasting," and "hyper-local" public health responses [23]. For example, in one peer-reviewed study, a team of public health researchers from the CDC and local public health departments conducted wastewater surveillance on one public school in Jefferson County, New York [32]. Based on their results, Kappus-Kron et al. argue that all schools should create an emergency plan to undertake wastewater surveillance during public health emergencies, which they characterize as a more precise approach to public health that would avoid unnecessary school closures. These data collection projects offer a vision of public health that is hyper-local and hyper-responsive to quickly changing conditions during an outbreak, made possible through partnerships between data scientists and public health fieldworkers.

Near real-time surveillance was used during the Covid-19 pandemic to direct limited resources to those most in need. The article "Evaluation of a Targeted COVID-19 Community Outreach Intervention: Case Report for Precision Public Health" (2023) reported on the results of an agency-academic collaboration to create a targeted educational outreach intervention in Brownsville, TX—a U.S.-Mexico border town with high rates of poverty, a large uninsured population, and high rates of comorbidities such as Type 2 diabetes [33]. Seeking to deliver public health interventions based on granular data, the research team targeted specific census tracts based on daily SARS-CoV-2 positive test counts. The intervention consisted of a bilingual door-knocking campaign with Covid information leaflets and, later, of radio advertising, social media posts, vans with loudspeakers, and interviews with news outlets. They found that this approach significantly increased the sustained use of free Covid testing sites after the intervention compared to census tracts that did not receive the intervention.

While similar to the risk-stratification strategy of the vulnerability indexes, this study paired near-real-time data collection with culturally-responsive distribution of limited resources in an emergency. Without the capacity to deliver door-to-door information to all of Brownsville, the research team was able to provide the intervention to 18 out of 48 census tracts using near real-time surveillance data:

> *What we present here is a case for precision public health that uses new technologies to improve local public health efforts by generating tailored and spatially targeted interventions. Our experiences and findings advocate…[for] granular population surveillance data sources on a national scale that can be leveraged to target interventions and deliver the correct intervention to the high-risk population in a timely manner [33].*

While the success of their intervention was due, in part, to new methods for data collection and analysis, they are careful to state that it was also achieved through low-cost interventions, longstanding agency-academic collaboration, and the dedication of staff and volunteers [33, 34]. This vision of addressing health disparities with educational outreach interventions has much in common with traditional public health, with the added agility of targeting the distribution of scarce resources using near real-time data. While the authors do advocate for increased investment in public health surveillance, it is clear from their reports that data alone is not enough to effectively respond to the needs of the community, while working towards an equitable pandemic response.

New articulation 3: pathogen sequencing

Pathogen sequencing is one of the success stories of the pandemic, in which sequencing data from SARS-CoV-2 was used to inform public health policy by identifying and tracking new variants of concern (VOCs) as they spread worldwide. Although genomic sequencing has been previously used for foodborne illness and virus surveillance, the 2013–2016 Ebola epidemic ushered in a new era of genome sequencing for viral outbreak response by providing "the first in-depth genomic anatomy of an epidemic" [35–37]. Because pathogen sequencing realizes the PPH vision of leveraging genomic technologies for public health, the term "precision public health pathogen genomics" has been used in both the Ebola and Covid contexts [38]. In the PPH and Covid-19 literature, pathogen sequencing and phylogenetic analysis join the list of novel "-omics" technologies with the potential to make public health interventions more precise [12–14].

In a study conducted in Hawai'i, precision public health pathogen genomics was deployed to inform policy to support health equity outcomes. In "Genomic analysis of SARS-CoV-2 variants of concern circulating

in Hawai'i to facilitate public-health policies" (2022), Maison et al. analyzed genomic sequences for SARS-CoV-2 variants of concern and compared these to the sequences of VOCs worldwide to create phylogenetic trees that show the most recent origin of VOCs found in Hawai'i. [13] Their goal was to use these phylogenetic trees to inform public health policy in Hawai'i during the pandemic. For example, since 76% of VOCs were found to have originated most recently from California, Maison et al. suggest that travelers from California should be subject to additional screening and quarantining measures in order to protect the Hawaiian population from emerging SARS-CoV-2 VOCs [13]. Here, Maison et al. forward a notion of health equity informed by an analysis of how power and privilege generate health disparities; they recommend targeting wealthy vacationers for public health surveillance rather than Hawaiian residents made vulnerable to Covid by the tourist economy. Rather than triaging according to vulnerability as in the first two articulations, this article argues for an upstream approach that seeks to prevent unequal harm through policy action.

Limitations

Despite the fact that the number of PPH articles continued to grow during the pandemic, there were relatively few articles that described projects at the intersection of PPH and Covid-19. This supports our hypothesis that PPH remains "more of an aspiration than a reality" [39]. Due to the lack of articles that report empirical results, it is not possible to assess whether PPH approaches were more effective than traditional public health responses to Covid-19. We recommend further research comparing the cost and outcome of PPH vs. traditional public health approaches. For researchers interested in pursuing empirical research that focuses on health equity in PPH, we have included a list of helpful articles from our sample (Table 3) and a list of recommendations for centering health equity in PPH (Table 4).

The new articulations we trace between PPH and vulnerability indexes, near real-time surveillance, and pathogen sequencing are tentative and not (yet) established in public health literature and policy. While these new articulations bolster PPH by showing it to be relevant for cutting-edge global pandemic response, it remains to be seen whether these public health practices will be absorbed by the precision imaginary, or whether they will

Table 3 Relevant Articles for PPH and Health Equity Researchers from our Data Set

Article on Data Equity in PPH	Geneviève et al 2022 [27], Mays et al 2022 [28], Allen et al 2023 [29]
Case Study in Using PPH in Community-Centered Projects	De La Cerda et al 2023 [33], Blackburn et al 2022 [34]
Case Study in Using Pathogen Sequencing for Health Equity Policy	Maison et al 2022 [13]

Table 4 Recommendations for Centering Health Equity in PPH

PPH tools/methods such as vulnerability indexes, near-real time surveillance and pathogen sequencing can be incorporated into public health research and interventions. Below are some questions, considerations, and recommendations for public health researchers considering PPH methods:
1. Consider the cost of big data approaches vs. the benefit before adopting PPH methods.
2. Center health equity questions in PPH research.
3. Go beyond risk stratification and address the root causes of health inequity.
4. Ground research and interventions in robust community partnerships at all stages of the research process.
5. Create interdisciplinary research teams that include social sciences and humanities scholars to better understand "the mechanisms that perpetual health disparities" [29]
6. Review relevant literature on bias in data collection and interpretation and consider the politics of data in your project. Is the data collection sufficient or is it defective in some ways? Who and what is left out? What biases are (re)produced? Whose lives are protected and whose lives are made vulnerable within data surveillance infrastructures?
7. Pay attention to questions of data equity in data collection, dissemination, and usability for minoritized communities [28]. Review the FAIR Guiding Principles for scientific data management and stewardship and the CARE principles for Indigenous data governance [41]. Make sure data is findable, accessible, interoperable, and reusable. Contribute to the larger project of creating "improved, harmonized, and nationwide data collection systems that are as free a possible from the influences of structural racism and inclusive of all racial and ethnic groups" [27].
8. Assess PPH projects to determine whether they have met their health equity goals. Allen et al. recommend that researchers "use validated measures and self-report to assess racial equity and racism, including qualitative methods to amplify the voices of those with lived experiences of racism" [29].

be brought together with other visions for public health and means of achieving health equity.

Conclusion

During the Covid-19 pandemic, the definition of PPH remained stable; however, PPH was still often framed as future-oriented with very few studies that applied PPH to Covid-19. For the few that have been published, we found that authors articulated the imaginary of PPH together with the Covid-era public health practices of vulnerability indexes, near real-time public health surveillance, and pathogen sequencing, demonstrating the relevance of PPH for pandemic response. In all but the Hawaiian example, the vision of health equity that emerges from this research is one where epidemiological surveillance data is used to create risk stratification to direct resources to the most vulnerable—an approach that fails to address the structural causes of increased exposure and severe outcomes.

While our analysis shows that data-driven PPH methods can be compatible with community-centered approaches in ways that strive toward health equity, it remains crucial to address the structural causes of unequal vulnerability and to address how inequalities can be (re)produced by the data itself. Even when a data-driven approach might be an effective public health strategy, it is important to consider how populations are counted, who and what is left out, what biases are (re)produced, and ultimately, whose lives are protected and whose lives are made vulnerable within data surveillance infrastructures [40]. These are questions that are important to ask throughout the study design, research, analysis, communication, intervention, and assessment stages of the research (Table 4). If PPH is to make good on its promise to promote health equity, attention to the politics and cost of data, data collection, data analysis, and data infrastructures is needed. In this regard, we were especially heartened by PPH articles that explicitly address data equity, antiracism, and the importance of interpreting data in the "context of the lives, risks, and stories of those whom the data are meant to help" [28].

Alongside calls for data equity, we would also like to stress that data-driven risk stratification is not the only vision of health equity possible. While vulnerability indexes and real-time surveillance might help distribute limited resources in an emergency, this approach should not be seen as the default solution for endemic public health problems and long-term community-based work. Although investment in data infrastructure may help triage in a pandemic, it must be paired with a commitment to addressing the upstream social determinants of health and understanding people in vulnerable communities as active agents of change, rather than passive subjects of public health surveillance. Whether PPH is a flash in the pan or here to stay, it is important to continue to consider whether and in what circumstances investment in PPH can support health equity goals or whether public health dollars are best invested elsewhere.

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Authors' contributions
M.K. and L.M. conducted the literature review in PubMed and supervised a graduate student research assistant. M.K. conducted the hand search of Google Scholar, decided on inclusion/exclusion criteria, and read all included articles. L.M. completed the web search of institutional actors promoting PPH for Covid-19 response. M.K. drafted the article. L.M. edited the manuscript and added insights from the web search. Both authors finalized the manuscript.

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Competing interests
The authors declare no competing interests.

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