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Technical Notes: Methodology for Developing the Local Public Health Resources Index (LPHRI), 2025 Release

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Introduction and Framework

The Local Public Health Resources Index (LPHRI) focuses on local public health resources needed to implement outbreak preparedness and response activities. The COVID-19 pandemic spurred interest in exposed the need to rebuild and transform public health infrastructure, including bolstering the public health workforce and improving public health data systems [1-3]. In 2022, the U.S. Centers for Disease Control and Prevention (CDC) released a Public Health Infrastructure Grant (PHIG), a multi-billion dollar investment that focuses on three key strategic areas: workforce, foundational capabilities, and data modernization [4]. Additionally, funding for public health continues to be an important impactful factor, with prior research linking local public health expenditures to declines in preventable causes of death [5].

To our knowledge, aside from surveys of samples of local public health departments, no comprehensive database of local public health resources in the U.S. exists. Therefore, we sought to bring together local-level data on these topics. Recognizing the importance of these categories of preparedness, and based on feedback from technical advisors, we created the following framework for the index:

- Workforce Capacity: what workforce is currently available in the public and private sector related to public health preparedness?
- Data Modernization/Technology Innovations: to what extent have new methodologies or technologies been adopted to improve public health preparedness, including data infrastructure and biosurveillance capabilities?
- Public Health Expenditures: what are the total local public health expenditures in the geography?

Through a literature search and consultation with technical experts, we identified two major groupings of workers that are critical to public health preparedness. First, the local public health agency workforce is an essential component of preparedness and response, including:

- Epidemiologists and data analysts, who conduct surveillance, investigation, and reporting activities
- Environmental health workers, who enforce environmental regulations that reduce disease transmission (e.g. foodborne diseases, water-borne diseases, etc)
- Public health laboratory workers, who staff laboratories that test samples as part of biosurveillance activities
- Nurses, who provide nursing support to communicable disease programs
- Community health workers and health educators, who provide a critical linkage and disseminate health information to communities
- Emergency preparedness workers, who create public health emergency response plans and provide related training

Second, since clinical laboratory capacity is important in diagnosing diseases presented in clinical settings, we included two key categories of clinical laboratory workers – phlebotomists and clinical laboratory technicians and technologists [6]. Additionally, given the role of pharmacists in distributing medical countermeasures (MCMs), we included pharmacists in this workforce category, which primarily includes private sector workers.

Third, public health expenditures at the local health department level were included as the final domain in the LPHRI.

Finally, we identified wastewater surveillance as a relatively new technology that was adopted more widely during the COVID-19 pandemic [7]. Use of this technology and reporting of results to the CDC National Wastewater Surveillance System (NWSS) are reflected in these indicators.

Data sources and definitions

Based on the framework described above and availability of data, the following indicators were developed for the LPHRI. In the 2024 release, in addition to using the most recently available data for the LPHRI at the time, we calculated a "prior version" using data that are approximately 1-2 years older than the latest version, so we can compare temporal trends in these indicators. For the 2025 release, we added additional data to reflect the most recently available data. For some indicators that are based on a two-year average (PH Workforce, PH Expenditures), we were only able to add a single year of data due to data availability, and thus these represent interim indicators. However, some indicators only rely on a single year of data and those have been updated with the most recently available data (Pharmacy Workforce, Wastewater Surveillance). The Clinical Laboratory Workforce indicators rely on two years of data and while numerator data were available for two years (2023 and 2024), denominator data were only available for 2023, so we used the same denominator data for both years; therefore, these indicators should also be treated as interim values.

We used the NACCHO Profile 2016 data as a starting point for identifying LHDs in the included states. However, since that time, there have been some changes, including newly formed LHDs and LHDs that ceded their authority back to the state. We updated the LHD map based on the changes noted on official state or professional organization websites [8-13].

Table 1 describes the data sources and definitions for each indicator.

Table 1. Indicators and Data Sources for the LPHRI

Domain	Indicator Name	Data Sources	Data Year(s) (2025 Release)	Data Year(s) (2024 Release)	Data Year(s) (Prior Release)	Description
Public Health Workforce	Epidemiology Staffing	California, Government Compensation data (2019-2023), Transparent California (2020, 2021) Nevada, Transparent Nevada (2019-2022) Arizona, Open Payrolls, govsalaries.com (2019-2023; note: not all years available for all LHDs) Utah, Transparent Utah: (2019-2023; note: not all years available for all LHDs) Oregon, OpenPayrolls.com (2023), Openthebooks.com (2023), not all LHDs available Washington, Openthebooks.com (2023), not all LHDs available Idaho, no data available for 2023.Denominator: American Community Survey (ACS) 5-year populations for corresponding years	2023*	2021, 2022	2019, 2020	Number of epidemiologists, data analysts, GIS analysts, research analysts in the local health department (LHD), per 100k population. Note: temporary contact tracers/disease investigators were not included in this category because these positions were not consistently reported across jurisdictions. Where maximum salaries were available in the dataset, the percent full time equivalent (FTE) was calculated before summing the total number of FTEs for this job category. The indicator is calculated by first calculating the number of staff per 100k population for each year, and then averaging over the 2 years.
Public Health Workforce	Nursing Staffing		2023*	2021, 2022	2019, 2020	Number of nurses employed in the LHD, per 100k population. This indicator includes all levels of nurses, such as registered nurses, nurse supervisors, licensed vocational nurses, and public health nurses. Where maximum salaries were available in the dataset, the percent full time equivalent (FTE) was calculated before summing the total number of FTEs for this job category. The indicator is calculated by first calculating the number of staff per 100k population for each year, and then averaging over the 2 years.
Public Health Workforce	Laboratory Staffing		2023*	2021, 2022	2019, 2020	Number of laboratory workers in the LHD, per 100k population. This indicator includes microbiologists, laboratory scientists, laboratory assistants, laboratory technicians, and related laboratory personnel. Where maximum salaries were available in the dataset, the percent full time equivalent (FTE) was calculated before summing the total number of FTEs for this job category. The indicator is calculated by first calculating the number of staff per 100k population for each year, and then averaging over the 2 years.
Public Health Workforce	Environmental Health Staffing		2023*	2021, 2022	2019, 2020	Number of environmental health workers in the LHD, per 100k population. This indicator includes environmental health specialists, environmental management personnel, environmental technicians, environmental inspectors, and related personnel. Where maximum salaries were available in the dataset, the percent full time equivalent (FTE) was calculated before summing the total number of FTEs for this job category. The indicator is calculated by first calculating the number of staff per 100k population for each year, and then averaging over the 2 years.
Public Health Workforce	Community Health Worker Staffing		2023*	2021, 2022	2019, 2020	Number of community health workers and health educators in the LHD, per 100k population. This indicator includes community health workers, community health technicians, community liaisons, community outreach workers, community service workers, health educators, peer counselors, and related personnel. Where maximum salaries were available in the dataset,

						the percent full time equivalent (FTE) was calculated before summing the total number of FTEs for this job category. The indicator is calculated by first calculating the number of staff per 100k population for each year, and then averaging over the 2 years.
Public Health Workforce	Public Health Emergency Preparedness Staffing		2023*	2021, 2022	2019, 2020	Number of emergency preparedness staff in the LHD, per 100k population. This indicator includes emergency preparedness workers, emergency planners, preparedness specialists, preparedness coordinators, and related personnel. Where maximum salaries were available in the dataset, the percent full time equivalent (FTE) was calculated before summing the total number of FTEs for this job category. The indicator is calculated by first calculating the number of staff per 100k population for each year, and then averaging over the 2 years.
Clinical Lab and Pharmacy Workforce	Clinical Laboratory Technologists and Technicians	BLS Occupational Employment and Wage Statistics Denominator: ACS 5-year populations for corresponding year up to 2023. For year 2024, the ACS 5-year population for 2023 was used due to data availability.	2023, 2024*	2021, 2022	2019, 2020	Number of clinical laboratory technologists and technicians per 100k population. Clinical laboratory technologists and technicians help prepare and process biological samples for laboratory testing. Clinical laboratory workforce is an important component of disease surveillance. The indicator is calculated by first calculating the number of staff per 100k population for each year, and then averaging over the 2 years.
Clinical Lab and Pharmacy Workforce	Phlebotomists	BLS Occupational Employment and Wage Statistics Denominator: ACS 5-year populations for corresponding year up to 2023. For year 2024, the ACS 5-year population for 2023 was used due to data availability.	2023, 2024*	2021, 2022	2019, 2020	Number of phlebotomists per 100k population. Phlebotomists play an important role in drawing blood and collecting specimens for clinical laboratory testing. Clinical laboratory workforce is an important component of disease surveillance. The indicator is calculated by first calculating the number of staff per 100k population for each year, and then averaging over the 2 years.
Clinical Lab and Pharmacy Workforce	Pharmacists	National Plan and Provider Enumeration System (NPPES) Denominator: ACS 5-year populations for 2023, 2022 and 2021	NPPES Jan 2025	NPPES Jan 2024	NPPES Nov 2022	Number of pharmacists per 100k population. The pharmacy taxonomy codes included are: - Pharmacist: 183500000X o Ambulatory Care: 1835P2201X o Critical Care: 1835C0205X o Geriatric: 1835G0303X o Nuclear: 1835N0905X o Nutrition Support: 1835N1003X o Oncology: 1835X0200X o Pediatrics: 1835P0200X o Pharmacist Clinician/Clinical Pharmacy Specialist: 1835P0018X o Pharmacotherapy: 1835P1200X o Psychiatric: 1835P1300X - Pharmacy technician: 183700000X Pharmacists dispense medications (including vaccines) and, as such, are a crucial workforce component for distributing medical countermeasures in response to a disease outbreak.
Public Health Expenditures	Public Health Expenditures	Arizona: public health department expenditures abstracted from Schedule F in agency budget reports (FY19, 20,	FY23*	FY21, FY22	FY19, FY20	Total local public health agency expenditures per capita. This indicator was calculated by dividing the total public health expenditures, divided by the population denominator, and

		21, 22, 23) for all counties except Yuma County, where records were abstracted from the agency website. California: City and County agency expenditures reports downloaded from state controller's office (FY19, 20, 21, 22, 23). Idaho: expenditures abstracted from Transparent Idaho (FY23). Nevada: expenditures abstracted from agency budget reports, FY19, 20, 21, 22, 23. Oregon: expenditures abstracted from agency websites (FY23). Utah: expenditures downloaded from Transparent Utah for the following health departments: Bear River, Central Utah, Davis County, Southeastern Utah, and TriCounty. Expenditures abstracted from agency budget reports for Salt Lake, San Juan, Summit, Tooele, Utah, and Wasatch counties, Weber-Morgan Health Department and Southwestern Utah Health Department (FY19, 20, 21, 22, 23). Washington: expenditures downloaded from Washington Financial Intelligence Tool (FY23). ACS 5yr population estimates for the corresponding year were used as denominators				averaged over the two years. Local public health expenditures have been linked to improvements in preventable mortality. Arizona: Expenditures for Public Health were included. California: Expenditures categorized as "Public Health" were included Nevada: Expenditures for Public Health departments were included. Budget information for this time frame was not available for Central Nevada Health District, which was established in December 2022. For several counties that do not have their own local health department (and whose public health services are provided by the state of Nevada), we did not include budget information, as we would not be able to distinguish the portion of the state budget that serves these counties. Utah: Expenditures for Health Districts or Public Health departments within county agencies were included.
Wastewater Surveillance	Wastewater Surveillance: population coverage	CDC National Wastewater Surveillance System (NWSS), most recently downloaded on Jan 23, 2025	2024	2023	2022	Population coverage for wastewater surveillance testing that is part of the CDC NWSS program. This indicator was calculated as the proportion of the county population that resides within a sewer shed participating in wastewater surveillance testing as reported to NWSS. Wastewater surveillance can be an important piece of a county's monitoring of population-level disease trends. Counties served by sewer sheds with the infrastructure to participate in wastewater surveillance may be better prepared to identify and track disease outbreaks. For sewersheds that crossed county borders, we assigned these sewersheds to the county where the majority of the sewershed was located.
Wastewater Surveillance	Wastewater Surveillance:	CDC National Wastewater Surveillance System (NWSS), more recently downloaded on Jan 23, 2025	2024	2023	2022	Frequency of wastewater surveillance testing that is part of the CDC NWSS program. This indicator was calculated by taking the

	frequency of testing					total number of days of wastewater surveillance testing in a year divided by the total number of months that testing was done. More frequent testing allows for faster detection of a signal, which can provide an early indicator of a new disease outbreak.

*Interim indicators – these are considered interim values because updated data were not available to calculate the 2-year average with a corresponding denominator.

Methods

1. Selection and aggregation of indicators

   1.1. Statistical methods to reduce dimensionality

   We used the Barnes-Hut implementation of the t-distributed Stochastic Neighbor Embedding (t-SNE) as an exploratory method for potential dimension reduction. While two distinct clusters were identified using t-SNE, we decided to keep all the initial indicators. For indicators using both the most recent data and the "prior version", there was a single cluster populated mostly with small counties and a second cluster with mostly large and medium sized counties. The analysis was conducted using Rtsne version 0.17. For the 2025 release, we did not perform additional dimension reduction because all indicators from the previous release were included in this update and no additional indicators were considered.

   1.2. Aggregating Indicators

   Before combining individual indicators, the data were centered and scaled. Each composite domain score is the arithmetic mean of all individual indicators within that domain. Due to the use of multiple imputation, a composite score was computed on each of the ten complete datasets and the final composite score is the pooled result of all ten composite indices. Due to data availability, domain scores were only included for public health expenditures and clinical laboratory and pharmacy domains. Additionally, only the clinical laboratory and pharmacy domain required computation because the public health expenditure domain is equivalent to the indicator.

   1.3. Conversion of county-level data and local health jurisdiction (LHJ) data

   Because some data were available at the county level and other data were available at the local health jurisdiction (LHJ) level, it was necessary to convert the datasets to the appropriate geography. To aggregate data points from a smaller geography to a larger geography, the conversion was done through a population-weighted average of the smaller geographies to calculate the value for the larger geography. For example, for health districts that consist of multiple counties, the health district value for an indicator is calculated as the population-weighted average of the county-level indicator values. Conversely, when converting data from a larger geography to a smaller geography, such as when a county contains more than one LHJ, the LHJ's within that county will all be assigned the same indicator value as the county in which the LHJ is located.

   1.4. Weighting

   Due to the absence of convincing empirical evidence suggesting the use of unequal weights, we applied equal weights to all indicators thus allowing for equal contribution to the composite domain score. Expert opinions can also be used to guide weighting decisions and can be considered for future releases.

2. Diagnostics

2.1. Missing Data

There was some degree of missing data present in ten of the twelve indicators. The indicators calculated for the 2024 release had 149 missing observations across all twelve indicators. There were 39 incomplete records amounting to 32% of the data. The phlebotomy indicator had the most missing records with 23 total missing observations. The set of "prior version" indicators (i.e. using data that is not the most recent available) had a total of 282 missing observations across all twelve indicators, resulting in incomplete cases in a total of 62 records or 51% of the data. Of these missing records, 45 included the phlebotomy indicator. Multiple imputation with classification and regression trees (CART) via the MICE package (version 3.16.0) in R was used to obtain a complete dataset. Pooled results from the ten complete datasets produced with multiple imputation were used for all analyses. The data displayed on the webpage only uses imputed data for composite domain scores, while the display of individual indicator scores only use non-imputed data. A sensitivity analysis was conducted to assess the impact of multiple imputation and the method of imputation used. The imputation methods we considered were classification and regression trees, Bayesian linear regression, and predictive mean matching.

For the 2025 release, there was also missing data for the 12 indicators. Notably, the two wastewater indicators were missing 56% of the data and each of the six public health workforce indicators had 38% missingness. Due to the high degree of missing data in the indicators that comprise the public health workforce domain and the wastewater surveillance domain, we determined that imputation was not appropriate for these eight indicators. For the remaining four indicators, the degree of missingness was minimal and thus we carried out multiple imputation with CART via the MICE package in R as in the 2024 release. Again, imputed data were only used to develop composite domain scores.

2.2. Indicator Distributions

The distributions of all individual indicators were evaluated. All wastewater indicators exhibited a strong degree of right skewness. To minimize undue influence on the composite index, the wastewater indices were log transformed. All other indicators were left untransformed.

2.3. Correlations

In order to obtain a complete correlation matrix to evaluate the correlations between all individual indicators, the imputed data were used. As expected, the two wastewater indicators are positively correlated with each other and the two clinical laboratory staffing indicators are positively correlated with each other. Similar degrees of correlation exist among the version using the most recent available data and the "prior version" of data. For the 2025 release, no such correlation matrix was produced due to the high degree of missing data.

3. Sensitivity Analysis

   We compared the distribution of the final composite domain scores as produced by three different multiple imputation techniques: classification and regression trees (CART), Bayesian linear regression, and predictive mean matching, as well as no imputation. The final composite domain scores (latest available data and previous release) were robust to the method used to handle missing data.

4. Validation

   No attempt at validation has been made for the 2025 interim release.

Strengths and Limitations

In addition to the novelty and strengths of this analysis, there are some limitations that should be noted regarding the data used in the LPHRI. These limitations are all within the normal scope of most research projects and should help guide the user in interpreting and using the data.

While we have made attempts to minimize missing data, there are still instances where data were not readily available. For some indicators, we averaged over two years of data, such that if one of those two years were missing, then the indicator would simply reflect the single non-missing year of data. Additionally, we have employed statistical techniques to impute missing data, which improves the validity of our analytic results.

We recognize that the efforts to modernize public health data systems are essential components of the PHIG and other related initiatives. The National Association of County and City Health Officials' (NACCHO) 2024 profile report on Public Health Informatics identified that almost 3 in 5 local health departments had existing data modernization efforts underway, and the report provides details on the types of informatics efforts ongoing [14]. However, implementation of these initiatives is still in the early stages, so systematic data at the LHJ level are not widely available. As these efforts mature, even more robust data may be added to the LPHRI in the future. Table 2 includes descriptions of some additional data limitations pertinent to specific indicator groupings.

Table 2. Data limitations pertaining to specific indicators or domains.

Indicators	Limitations

Public health workforce indicators	Job groupings are based on our categorization of job titles. Some agencies have job titles that are less descriptive (e.g. Public Health Associate), and therefore could not be categorized. For this reason, it is possible that we are undercounting the staffing levels at some agencies. Additionally, while some agency data were available by department (e.g. Public Health Department), other agencies did not provide department information; as such, it is possible we may have included some employees who work in other departments (e.g. nurses can work in health services or public health departments), and some agencies have combined "health and human services" departments. Therefore, the ability to distinguish public health employees from other employees within the agency may be limited. Additionally, this method in enumerating public health employees is not able to characterize the effectiveness (output) of the employees. For FY23, many states and LHDs did not have employment data posted on public websites, so these data are missing.
Clinical laboratory technicians and technologists, Phlebotomists	For non-metropolitan areas, the Bureau of Labor and Statistics only provides regional estimates (e.g. several counties combined). Therefore, many adjacent rural counties will have the same estimate because a regional estimate has been applied.
Public health expenditures	Agencies may have different ways of defining what expenditures are within public health, environmental health, or other departments or categories, so there may be some inherent differences across agencies based on their definitions. The fiscal years used in the LPHRI includes funding to health departments that was provided as part of the COVID-19 public health emergency. Therefore, decreases in public health expenditures following the end of the COVID-19 emergency may simply represent the end of this emergency funding rather than a reduction in core public health funding. Tracking public health expenditures into future years should provide a clearer picture of local public health investments over time. Expenditures data were not adjusted for inflation.
Wastewater surveillance indicators	We applied some simplifying assumptions for sewersheds that serve households in more than one county. Across the 7 states, there are approximately a dozen sewersheds that served 2 counties, and no sewershed served 3 or more counties. For sewersheds that crossed county borders, we assigned these sewersheds to the county where the majority of the sewershed was located. These assumptions lead to underestimating population coverage in the counties that included only a smaller portion of the sewershed, and overestimating the population coverage in counties that included the larger portion of the sewershed. The wastewater surveillance indicators only includes surveillance activities that are reported to the CDC NWSS program. Other wastewater surveillance activities that are not reported to this program are not captured in these indicators.

Given the findings from our validation analysis of the 2024 release, where we did not find any evidence of a meaningful association between LPHRI domains or indicators and the aforementioned validation outcomes, we recommend that the LPHRI should be used as a comparative tool to assess relative resource levels and not as an assessment or predictor of the ability for a region to prevent or withstand a future outbreak.

One notable strength of the LPHRI is its focus on local public health preparedness, with unique indicators developed specifically for this project. To our knowledge, there is no publicly available unified dataset of local public health workforce statistics or local public health expenditures. The LPHRI allows users to make comparisons across counties and local health districts and access these unique data elements that can help inform decision-making about preparedness gaps and local investments.

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