The U.S. COVID-19 Vaccine Coverage Index (CVAC) Methodology

Developed by Surgo Ventures

Version 1, Published February 23, 2021
Updated as of March 4, 2021[1]

Context 2

Guiding principles 2

Index Design 3
- Selection and interpretation of historic undervaccination indicators 7
- Capturing COVID-19 Vaccine-specific factors 7

Index computation 8
- Missing Data 8
- Stepwise ranking procedure 9

Validation 9
- Convergent validation 9

Limitations of the index 10
- Data availability 10
- Static construct 10

Index Updates 11

[1] CVAC subtheme names have been updated for clarity as to what they are measuring.

Context

With COVID-19 vaccines readily available, policymakers have rushed to deliver vaccines to the public. Such a large-scale distribution of the COVID-19 vaccine has brought new challenges beyond standard vaccination programs, from ultra-cold chain storage requirements that complicated supply chain logistics to many Americans reporting hesitancy towards getting the vaccine. Even with vaccines available at distribution sites and the intent to get the vaccine, equitable access remains a barrier in question, which has been an ongoing challenge with testing throughout the pandemic. Without substantial vaccine coverage, the vaccine cannot deliver the anticipated long-term clinical and socioeconomic benefits that come with ending a debilitating pandemic.

Decision-makers need to understand the unique factors that could make vaccine rollout more challenging in some communities more than others. To identify these differences, we created the county-level U.S. COVID-19 Vaccine Coverage Index (CVAC) to highlight where and why communities should be concerned about vaccine coverage barriers. The index measures the level of concern about COVID-19 vaccine coverage based on supply and demand-side barriers, including contextual factors, care-seeking behaviors, and historical vaccine coverage data. The tool can be used as a resource for policymakers to inform a precision response, targeting the right communities with the right interventions, to roll out the COVID-19 vaccine efficiently and equitably.

Guiding principles

- The index measures the level of concern about difficulties in achieving high vaccine coverage in each county.
- The index captures a comprehensive set of barriers, both supply- and demand-side factors, based on historical evidence, unique COVID-19 vaccine distribution characteristics, and COVID-19 poll results on vaccine hesitancy.
- The index is *modular* to reflect the multidimensional nature of vaccine coverage, and that two communities could be at a high level of concern for different reasons.
- The index will be validated and updated as COVID-19 vaccination data becomes publicly available across granular geographies.
- To provide actionable policy insights, conceptual simplicity and ease of interpretation were given preference over internal statistical consistency and theoretical models when designing the index and its constituent themes.
- Construction of the CVAC was guided by the CDC's Social Vulnerability Index methodology as well as the ten steps outlined in the Handbook on Constructing

Composite Indicators (COIN), and inspired by our U.S. COVID-19 Community Vulnerability Index (CCVI) .

Index Design

The COVID-19 Vaccine Coverage index (CVAC) is a measure of the expected difficulty a community may face in achieving rapid, widespread COVID-19 vaccine coverage; a higher score indicates a higher level of concern for COVID-19 vaccine rollout. The CVAC is a modular index where the final score can be broken down into five different themes that reflect barriers to vaccine coverage:

1. Historic undervaccination
2. Sociodemographic barriers
3. Resource-constrained health systems
4. Healthcare accessibility barriers
5. Irregular care-seeking behavior

Each theme is constructed from subthemes, which comprise multiple indicators. Each indicator and subtheme is equally weighted when calculating subtheme and theme level scores, respectively. Similarly, each theme is equally weighted in the final CVAC calculation. Table 1 provides an overview of the architecture and data sources.

Development of the CVAC architecture was informed by literature search and consultation with subject-matter experts to identify barriers to COVID-19 vaccine coverage and unique COVID-19 vaccine-specific characteristics affecting supply and demand. This included a review of historical evidence (i.e. determinants of vaccination coverage), COVID-19 vaccine poll results, and vaccine-related guidance from governing bodies (e.g. the CDC). Indicators were selected based on quality and consistency of evidence over time and across populations, data availability, recency, and completeness with low frequency of missing data. The index structure went through several iterations with the final framework approved by subject-matter experts.

Table 1. Indicators for the COVID-19 Vaccine Coverage Index

Theme		Sub-theme	Indicator(s)	Source	Geo
1	Historic Undervaccination	Lower Coverage & Higher Refusal Rates	Proportion of children age 35 months receiving ≥ 1 dose MMR vaccine	2016-2019 National Immunization Data	State
			Proportion of children age 35 months receiving ≥ 3 doses of polio vaccine		
			Proportion of children age 35 months receiving ≥ 4 doses DTaP vaccine		
			Proportion of teens age 13-17 years up-to-date on HPV vaccine		
			Proportion of adults receiving flu vaccine	2018 BRFSS & PolicyMap	County
			Proportion of Medicare beneficiaries receiving pneumococcal vaccine	2018 CMS Mapping Medicare Disparities Tool	
			Nonmedical exemption rate from child school immunization (refusal of vaccines for personal religious or philosophical reasons)	(Zipfel, 2020)[2]	County
2	Socio-demographic Barriers	Socio-Economically Disadvantaged	Proportion of racial and ethnic minority groups (Black, Hispanic, Native Hawaiian & Pacific Islander, and Native American & Alaska Native individuals; per ACS definition)	2014-209 U.S. Census American Community Survey (ACS) 5-year estimates	County
			Proportion of individuals without a bachelor's degree or higher		
			Median household income		
			Average unemployment rate March-October 2020	2020 Bureau of Labor Statistics Labor Force	

[2] Zipfel, C.M., Garnier, R., Kuney, M.C. et al. The landscape of childhood vaccine exemptions in the United States. Sci Data 7, 401 (2020). https://doi.org/10.1038/s41597-020-00742-5

				data	
			Proportion of individuals living below poverty level	2014-209 U.S. Census American Community Survey (ACS) 5-year estimates	
		Lack of Access to Information	Proportion of households without an internet connection		
			Proportion of individuals without a smartphone		
			Proportion of limited English-speaking households		
3	Resource-constrained Health System	Low Healthcare System Capacity	Vaccination provider workforce per capita (Medical Doctors[3], Doctors of Osteopathy[4], Advanced Practice Registered Nurses[5], Physician Assistants, Pharmacists*)	2020 Health Resources and Services Administration, Area Health Resources File	County
				*2020 BLS Quarterly Census of Employment and Wages	
			Infrastructure for vaccine administration per capita (Hospitals*, Urgent Care Facilities*, Veterans Health Administration Medical Facilities*, Federally Qualified Health Centers and look-alikes**, Pharmacies***)	*2018, 2020 Department of Homeland Security HIFLD	County
				**2020 Health Resources and Services Administration	
				***2020 Department of Homeland Security HIFLD, Rx Open	
		Weak Healthcare System	AHRQ Prevention quality indicator (PQI) overall composite[6]	2018 Centers for Medicare & Medicaid Services Mapping Medicare Disparities Tool	County
			Health spending per capita	2014 Centers for Medicare & Medicaid Services Health Expenditures by State of Residence	State

[3] Total active MD's non-federal and federal.
[4] Total active DO's non-federal and federal.
[5] Advanced practice registered nurses (APRN) includes advanced practice midwife, certified registered nurse anesthetist, clinical nurse specialist, and nurse practitioner.
[6] A higher PQI indicates a higher rate of preventable hospital stays, indicating poor quality of outpatient care (AHRQ, 2020).

			Total healthcare funding per capita (CDC COVID Funding, Public Health Emergency Preparedness (PHEP) funding, CDC grant funding for Immunization and respiratory Diseases and Vaccines for children, State Public Health Funding*)	2019 CDC, Center for Preparedness and Response *2019 Trust for America's Health	
4	Healthcare Accessibility Barriers	Barriers due to Cost	Proportion of individuals without health insurance coverage	2014-2019 U.S. Census American Community Survey (ACS) 5-year estimates	County
			Proportion of adults who reported that there was a time in the past 12 months when they needed to see a doctor but could not because of cost.	2018 BRFSS & KFF	State
		Barriers due to Transportation	Households without vehicle ownership	2014-2019 U.S. Census American Community Survey (ACS) 5-year estimates	County
			Transit Connectivity Index (TCI)	AllTransit	
5	Irregular Care-seeking Behavior	Lack of a Designated Medical Home	Proportion of adults who reported that they did not have one or more individuals they thought of as a personal doctor or health care provider.	2018 BRFSS & PolicyMap	County
			Percent of Children without a Medical Home (children must meet the criteria for adequate care on the first three components: personal doctor or nurse, usual source for care, and family-centered care Any children who needed referrals or care coordination must also meet criteria for those components in order to qualify as having a medical home.)	2017 NSCH & KFF	State
		Lack of Routine Care Visits	Proportion of individuals without visits to doctor for routine checkup	2018 BRFSS & PolicyMap	County
			Percent of Children (ages 0-17) who did not have both a Medical and Dental Preventive Care Visit in the Past 12 Months	2017 NSCH & KFF	State

Selection and interpretation of historic undervaccination indicators

The historic undervaccination theme includes standard vaccine coverage and non-medical exemption rates (refusal of vaccines for personal reasons). We considered standard adult, adolescent, and child vaccine coverage indicators and selected the ones available at the most granular geographic level. For a given vaccine, several indicators were available by age and dosage. In such cases, we selected indicators based on the most broad categorization (e.g. complete dosing by age per CDC recommendations) and strength of correlation with other vaccines. In general, we found higher correlation among vaccines from same age groups i.e. correlation was higher among childhood vaccines, including MMR, Polio, DTaP than with adult vaccines like flu or pneumococcal. We selected vaccine coverage indicators for inclusion that were representative of multiple indicators. For example, one of the polio vaccine coverage indicators was highly correlated with DTaP (r=0.78) and Hepatitis B indicators (0.91), so we selected polio vaccine indicator and discarded the other two.

Interpretation of the historic undervaccination theme differs from other CVAC themes. This theme measures outcomes (vaccine coverage) while other themes capture barriers to getting vaccinated. Historic undervaccination was added to the CVAC to integrate observable and non-observable underlying factors that could drive COVID-19 vaccine coverage. Based on historical evidence, standard vaccine coverage rates are expected to be correlated with COVID-19 vaccine coverage as was the case with the H1N1 pandemic, where flu vaccination coverage predicted H1N1 vaccination rates.[7]

Capturing COVID-19 Vaccine-specific factors

COVID-19 vaccine rollout is unlike any other in its speed and scale of rollout. COVID-19 polls have already indicated vaccine hesitancy among socio-economically disadvantaged groups, similar to patterns seen in non-COVID vaccines. Vaccinating millions of Americans in a few short months is bound to face novel challenges beyond traditional vaccine rollout. To capture these novel challenges, we added indicators that are not traditionally considered barriers to vaccine coverage in the community. For example, we have added state-level COVID-19 specific funding from the CDC and public health emergency preparedness funding available to capture added healthcare system strength during the COVID-19 pandemic. We have also added indicators on access to smartphones and internet to capture community access to information about COVID-19 vaccination sites, eligibility, or

[7] Davila-Payan C, Swann J, Wortley PM. System factors to explain H1N1 state vaccination rates for adults in US emergency response to pandemic. Vaccine. 2014 May 23;32(25):3088-93.

2-dose reminders. Healthcare system capacity indicators, including provider types and vaccine distribution locations, were selected based on CDC guidance.[8]

Index computation

The overall CVAC composite score and scores per each of the five CVAC themes were calculated at state and county levels, ranking each geographical region on a 0-1 scale of the level of concern about COVID-19 vaccine coverage (0 = least concerning, 1 = most concerning). To compute the county-level index, we used county-level indicators when available and state level indicators otherwise. State-level indicators were copied down to all counties within one state (i.e. no small area estimation was applied). To compute the state-level CVAC, we used state-level data for the same indicators from the same data sources. Geographic boundaries were defined by the 2010 Census, and data processing and index construction were conducted using R, a statistical computing software.

Missing Data

Indicators with more than 20% missing data across geographies were not considered for index inclusion with the exception of the rate of non-medical exemptions for childhood vaccines (Th1_R_NME). For final CVAC indicators with missing data, values were imputed with median values across all counties for county-level CVAC, and across states for state-level CVAC.

Non-medical exemptions data
In case of Th1_R_NME, data is missing for 70% counties. However, not all states allow non-medical exemptions for childhood vaccines, so we imputed missing values using the median exemption rate in states where data were available. This indicator was included despite high missingness as a proxy measure of underlying community-level vaccine hesitancy..

Relationships between indicators
We ran Pearson correlations to characterize the relationship between indicators, subthemes, and themes. Indicator-level correlations were stronger amongst indicators within themes than across themes with a few exceptions. For example, we observed high correlation between some indicators in themes 1, 4, and 5, where areas with healthcare accessibility barriers and poor healthcare behaviors were more likely to have lower historic vaccination coverage. Rather than change the index structure based on statistical findings,

[8] COVID-19 Vaccination Program Interim Playbook for Jurisdiction Operations, Version 2.0. Centers for Disease Control and Prevention (CDC). October 29, 2020

the indicators were kept as is because we considered the structure easier to act upon by health officials. Principal component analysis of indicators showed similar results with the first two components capturing 34% of the variance in the data.

Stepwise ranking procedure

We used a stepwise percentile ranking process to generate a compositice CVAC score and one score per theme that provides a comparative measure of concern over COVID-19 vaccine coverage across geographic regions. First, indicator values were transformed into a percentile, a statistical measure ranking each data point in relation to other geographies (e.g. the 20th percentile represents the value below which 20% of the data points fall). Indicators ranks were then aggregated up to subthemes and ranked again across geographic regions. Subtheme ranks were aggregated into themes and then ranked to obtain the final theme scores. Finally, the theme scores were aggregated and ranked across geographies to create CVAC scores for each geographic unit (county and state). This methodology is similar to CDC's Social Vulnerability Index (SVI) and our US COVID-19 Community Vulnerability Index (CCVI). These stepwise aggregations of subcomponents were weighted equally across indicators, subthemes, and themes.

Unless otherwise stated in the report's findings, communities with a "high" level of concern are in the top two-fifths of the data (e.g. counties with a CVAC score greater than 0.6), and those with a "very high" level of concern are in the top one-fifth of the data (e.g. counties with a score greater than 0.8). For the analysis of secondary data, including the vaccine rollout numbers, we refer to "high" as the top one-third of counties or states.

Validation

At the time of construction, granular vaccine coverage metrics across all U.S. geographies were not available for CVAC validation. Rather than wait for this data, the CVAC was launched in the interest of supporting decision-makers with COVID-19 vaccine planning for large-scale distribution. Validation analyses are ongoing as more data becomes available at a granular level nationally and will be published after the initial release of the index.

Convergent validation

Because historic undervaccination coverage is an outcome, the CVAC was calculated without Theme 1 to assess the relationship between CVAC barrier-oriented themes and standard vaccine coverage. Pearson correlations (r) at state (r=0.34) and county (r=0.43) level indicated that there is a moderate level of agreement between historic undervaccination and a CVAC barrier composite (i.e. themes 2-5 only), showing that the index does capture some level of barriers to general vaccine coverage. This moderate relationship also indicates that historic vaccination coverage levels and the other themes capture unique components to the index (i.e. barriers limiting COVID-19 vaccine coverage).

Limitations of the index

Data availability

There are a multitude of barriers driving vaccine coverage that are not measurable at a granular level across geographies. This issue is in part offset by the inclusion of outcomes data (i.e. vaccination coverage) in the historic undervaccination theme. A subset of indicators were only available at a state-level, and were copied uniformly down to counties within the state's boundaries. This reduces county-level precision of the index on some aspects like public health funding, childhood vaccination rates, and healthcare accessibility barriers. Childhood vaccine coverage indicators were sourced on September 8th, 2020 from the 2011-2016 CDC ChildVaxView database, prior to data updates with 2017 data availability. We continue to search for reliable, granular vaccination coverage metrics.

Of the data available to capture the total vaccination provider workforce per capita, pharmacist occupation data from the Bureau of Labor Statistics (BLS) was only available at a state level. To add geoprecision, a county-level proxy indicator was used from the BLS Quarterly Census of Employment and Wages (QCEW). Though this data includes all staff employed at pharmacies, we make the assumption that the proportion of pharmacists at each location scales linearly with total staff.

Static construct

The CVAC is a static index that does not capture real-time metrics (e.g. the number of vaccine distribution sites open per capita at a given point in time). The challenges surrounding the introduction of a new vaccine are complex and dynamic in nature with elements that may not be predicted by historic factors alone. However, CVAC, by capturing the underlying, baseline community-level characteristics, offers a window into the inherent challenges a community may face during any phase of COVID-19 vaccine rollout relative to other geographies.

Index Updates

The modular design of the CVAC offers the potential to update the index. Updates are expected as validation continues with the availability of granular, time-series COVID-19 vaccination and hesitancy data. Index data is expected to be updated with the upcoming release of 2020 census data at the end of March. Subsequent releases will be documented with a description of changes for transparency.

LEARN MORE:
Explore the CVAC Online

Contact Us

Please cite this guide as:
Surgo Ventures (2021) The U.S. COVID-19 Vaccine Coverage Index (CVAC) Methodology, Version 1. http://precisionforcovid.org/cvac

Acknowledgements: We are grateful for expert feedback and comments on this work from (in alphabetical order) Amanda McClelland and the Vaccine and Community Engagement teams at Resolve to Save Lives, Puneet Dewan, Regan Marsh, Daniel Salmon, Prashant Yadav, and the CDC Social Vulnerability Index team (Danielle Sharpe, Barry Flanagan, Elaine Hallisey, Grete Wilt).

Version 1, Published February 23, 2021
Updated as of March 4, 2021