Africa COVID-19 Community Vulnerability Index: Methodology

Context

As national governments scale up their response to COVID-19 around the world, existing stark disparities between communities have only deepened. It is not enough to uniformly scale-up national-level response - countries need to understand the unique factors that make some communities or regions more vulnerable than others. To highlight these differences Surgo created the Africa COVID-19 Community Vulnerability Index (Africa CCVI) for 48 African countries that ranks 751 sub-national units (administrative level 1) using a variety of epidemiological, economic, and systemic factors. The index and country-specific factsheets are hosted at precisionforcovid.org/africa, and the CCVI scores are available as spreadsheets here.

It is important to understand that in our work, the term “vulnerability” refers to the impact of the virus on a community *after the virus arrives*. This is different from trying to understand *where the virus will hit first (susceptibility)*. In the US, for example, we found that vulnerable communities were later to get hit. However, once it arrived the virus spread faster and was more deadly in vulnerable communities.

Guiding principles

We set out to create an index that satisfied several criteria:

- Vulnerability is expressed at the *subnational* level (rather than a single score per country);
- All African countries are included insofar data availability allows;
- The index is *modular* to reflect the reality that vulnerability is a multi-dimensional construct, and two regions could be vulnerable for very different reasons;
- The index reflects the science in terms of risk factors for COVID-19 both in terms of clinical outcomes and socioeconomic impact.

Themes, subthemes, and data sources

The Africa CCVI is modular in that the overall vulnerability score of a region can be broken down into 7 main themes, which themselves are constructed from subthemes. This table shows the anatomy of the index, alongside the data sources feeding into each subtheme. Each sub-theme is weighted equally when computing the theme score, and each theme is weighted equally for computing the overall index. Subthemes can consist of multiple underlying indicators (see Appendix 1)

Africa CCVI themes	Africa CCVI subthemes	Data Source(s)
Theme 1: Socioeconomic Status	Access to information	DHS
	Education	DHS
	Poverty	OPH
	Unemployment	DHS
Theme 2: Population Density	Population density	WorldPop
Theme 3: Housing type & Transportation	Access to transportation	DHS
	Connectivity by road	Global Roads Inventory Project
	Crowding in household	DHS
	Improved housing	Malaria Atlas Project
	Sanitation	DHS
Theme 4: Epidemiological Factors	HIV	IHME
	Other infectious diseases	IHME
	Obesity	DHS
	Diabetes	Published papers and custom calculation
	Hypertension	Published papers and custom calculation
	Smoking	DHS Survey
Theme 5: Health System Factors	Health Facilities per capita	WHO, Malaria Atlas Project, OSM
	Access to healthcare systems	DHS
	Healthcare system performance	DHS
Theme 6 Fragility	Civil Unrest	Uppsala University, ACLED
	Population of concern sites	UNHCR
	Food insecurity	DHS, IHME
Theme 7: Old age	Old Age	DHS

Data sources for nine individually-analyzed countries

We used uniform indicators from the same data sources as shown in the table above. Nine countries lacked data from some of the sources described above and required us to seek out country-specific data sets. We ensured data for each of the themes was available for these nine countries, however the exact variables and subthemes can differ from the “standard” data pipeline used for the majority of countries.

Country	Source 1	Source 2	Source 3
Libya	PAPFAM survey	Libya Open Data for Africa	Global Data Lab
Somalia	MICS survey	Somalia Open Data for Africa	Global Data Lab
South Sudan	MICS survey	South Sudan Open Data for Africa	Global Data Lab
Sudan	MICS survey	Sudan Open Data for Africa	Global Data Lab
Tunisia	MICS survey	Statistics Tunisia	Global Data Lab
Central African Republic	MICS survey	Central African Republic Open Data for Africa	Global Data Lab
Djibouti	MICS survey	Djibouti Open Data for Africa	Global Data Lab
Algeria	MICS survey	Algeria Open Data for Africa	Global Data Lab
Botswana	Botswana Demographic survey	Botswana Open Data for Africa	Global Data Lab

Index computation

The Africa CCVI is calculated for each country at the first administrative level, with regions defined by GADM (www.gadm.org).

Variable selection

Starting from an initial set of themes based on literature review and experience from the US index, we shortlisted indicators from various sources. We selected indicators based on subnational availability (either in raster form or per administrative region), recency, and amounts of missing data. As we continued to identify novel data sources and received feedback from partners, we refined the themes and individual indicators. We are still in the process of seeking improvements to the index, e.g. to add non-communicable diseases.

Estimating hypertension and diabetes at subnational level

Public data on non-communicable diseases at GADM1 level in a consistent format is almost non-existent across Africa, with the exception of obesity data from DHS. Given the important role of these factors in intensifying the effects of COVID-19, we devised a custom approach to estimate subnational prevalence of chronic conditions. We conducted a literature review on research articles that published subnational estimates for comorbidities identified as being risk factors for poor COVID-19 outcomes by the CDC for any of the 48 countries. We decided to add only diabetes and hypertension as there were a substantial number of studies of subnational prevalence for these conditions, but not for other diseases (such as chronic kidney disease and cancer).

We conducted an extensive search for articles, published since 2000, that estimated rural and urban prevalence of hypertension or diabetes for one or more countries included in our index.

This approach yielded rural versus urban prevalence of diabetes and hypertension estimates for 12 countries and 16 countries, respectively. Using this data we devised a two-pronged approach. First, we calculated the relative risk (RR) for urban versus rural populations in each country, and imputed RR for all remaining countries using the average RR across the 12 and 16 countries respectively (hypertension RR: 1.23; diabetes RR: 1.97). Though the actual prevalence is likely to change substantially over time, we assumed relative risk would be more stable. Second, we collected national-level estimates for diabetes and hypertension for all 48 countries. We then obtained rural and urban populations estimates for each country and 751 regions by combining the urban centers database from Global Human Settlement with World Pop population rasters. Combining these data points - country-level prevalence, urban to rural RR, and percentage of each country's population that is urban - we calculated the prevalence of each disease separately for urban and rural populations using the following equations (each variable other than RR is expressed as a proportion).

$$prevalence_{rural} = \frac{prevalence_{country}}{population_{rural} + RR * population_{urban}}$$

$$prevalence_{urban} = RR * prevalence_{rural}$$

This provided us with a *country-level* estimate of hypertension and diabetes prevalence for urban and rural populations. We then estimated *regional* prevalence of both conditions by taking an average of urban and rural prevalence weighted by the proportion of each region's population that is urban and rural.

Stepwise ranking procedure

Variables are represented by percentiles, 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). We created rankings prior to each aggregation step. First, indicator values for each administrative region were ranked relative to all administrative units in the dataset. These indicator rankings were aggregated to subthemes and then ranked again relative to all administrative units in the dataset. The same process was followed for aggregation of subthemes to the final six themes, and from the themes to the overall score.

This provided each region's vulnerability *relative to every other region on the continent*. To arrive at a vulnerability score relative to other regions *within the same country*, the themes and overall score were re-ranked within-country. Both scores are visualized on the website and available for download. Finally, for communication purposes, vulnerability was classified into quintiles: very low (<20%), low (20-40%), moderate (40-60%), high (60-80%), and very high vulnerability (>80%).

A detail that will only interest technical readers is that this type of aggregation - whereby each indicator is initially ranked against every other region in the data - has the desirable side-effect that indicators with little variance within-country end up hardly affecting the within-country

vulnerability scores for that country (because each region for the country gets similar ranks on that indicator when ranking against entire continent). If each indicator were to be ranked separately for each country, even variables with minimal variance would be forced onto a 0-100 scale, thus affecting the final score as much as an indicator that genuinely has high variance within that country.

For the nine countries with custom data sources, we ensured each theme was represented in the data, and we followed the same steps in terms of percentile rank aggregation. However, each country was aggregated entirely within-country, such that no scores relative to other regions are available.

The data were processed in R, with QGIS for geographic preprocessing and Tableau for some visualizations.

Missing data

Any potential indicator with more than fifty percent missing data across all regions was removed. For the remaining indicators we imputed missing values using median values within each country. Generally, missing data was not a major issue; rather, the available data was sometimes outdated (see limitations).

Validation

Whether our index truly captures vulnerability to COVID-19 will have to be validated over the medium term as data on the impacts of the pandemic in Africa become available. Nonetheless, we undertook several steps to validate our approach:

- Our US index, which is conceptually identical, successfully tracks metrics like speed of spread, mortality, availability of testing sites, and changes in mobility. The CDC lists the US CCVI as a resource on their website.
- We see similar patterns emerging in the Africa index: more vulnerable regions have tended to social distance less in 16 countries where mobility data are available.
- We discussed the index with a wide range of experts including from implementing partners, funders, and academia.
- We checked scores against known patterns of poverty, health insecurity, and conflict in several countries, as well as more detailed data on health systems to ensure our themes were capturing known patterns.

As more COVID-19 data from African countries becomes available, we will use the index to analyze the rate of COVID-19 spread and mortality rate.

Limitations of the index

Nine countries use different data source

Though 39 out of 48 countries in our index share the same data sources, 9 others use custom data sources. This means these 9 countries cannot be compared against the remaining 39, such that only vulnerability of a region relative to other regions *within the same country* are shown.

Limitations of rank scores

Ranking regions is helpful as it allows us to combine data from many sources that exist on different scales (e.g. percentages versus people/km^2). However, a rank can hide critical information in the raw data. As one dives deeper into the index and into subthemes for a particular country, we recommend looking at the raw data as well to get a sense for the magnitude of differences between regions.

Data recency

The issue of data recency is in part offset by using indicators that do not rapidly change year-on-year. Nonetheless, for several countries DHS data is only available pre-2010 (see Appendix 2). We are working to obtain country-specific data that is more recent, where available.

Proxy indicators

The issue of available indicators in particular affects Theme 4: Epidemiological factors, and Theme 5: Healthcare system factors. For epidemiological factors, non-communicable diseases such as cardiovascular disease have proven substantial risk factors for poor outcomes from infection [ref]. Unfortunately, these data are hard to obtain at the national level, let alone at the subnational level. We are actively seeking methods to estimate relative NCD prevalence across regions of a country based on other indicators. For healthcare system factors, key data such as hospital and ICU beds, and staffing numbers, are unavailable for most countries at the subnational level. This theme primarily consists of proxies of healthcare performance and access. We are looking to add country-specific data on healthcare capacity soon.

Updates to the index (changelog)

We regularly update the index as we identify improvements. The public data sheet has named versions in case previous versions need to be accessed.

V3. Add hypertension and diabetes and restructure several themes

Problem: Theme 4, epidemiological factors, did not include data for chronic non-communicable diseases like hypertension and diabetes, which have been shown to highly correlate with severe illness from COVID-19. Second, some indicators were very similar to others or grouped incorrectly under subthemes. Third, issues similar to V2 were found with several indicators in Kenya's data.

Solution: Due to lack of comprehensive subnational data on prevalence of hypertension and diabetes across African countries, we devised an approach, explained above, to estimate subnational prevalence for 48 countries. In addition to this, we restructured the themes by removing indicators that were highly correlated with another indicator under the same subtheme. We also rearranged the grouping on indicators under Theme 6 (Fragility). Lastly, we fixed issues similar to the V2 with Kenya data by using DHS data from higher geographic level (zonal) for GADM level 1 regions.

Impact on index: Theme 4 (Epidemiological factors) scores, both across and within, changed for several countries and regions. Restructuring of indicators resulted in score change across all themes except Theme 2 (Population Density) and Theme 6 (Fragility). Kenya's overall CCVI score increased from 0.05 to 0.18, moving it down to overall eighth on the top 10 least vulnerable countries.

Date: Released on Aug 13, 2020

V2. Update Theme 7 to correct for Kenya missing data issue

Problem: Kenya, one of the countries with DHS as the primary data source, did not have any data on three of the four indicators under Theme 7 (Age) for all regions except Nairobi. Given our strategy to replace any missing data with the median value of the indicators within the country, Nairobi's data was copied to every region in Kenya thereby reducing the variance to zero. Due to zero variance within the country and Nairobi's overall low values, we underestimated the theme 7 vulnerability for most of Kenya's regions.

Solution: Add over 60 years of age population data from World Pop as an additional indicator for all countries; calculate ranks for Th7 for Kenya separate from other countries and then join it to the main dataset for final theme ranking.

Impact on index: Kenya's overall CCVI score was raised from 0 to 0.05, with Ghana taking the position of overall least vulnerable country. Most regions in Kenya increased in Theme 7 vulnerability, thereby slightly increasing their overall vulnerability score as well. Other countries were not significantly affected.

Date: Release on July 16, 2020.

V1. Initial release

Date: Release on July 9, 2020

Appendices

Appendix 1: Full list of indicators used for majority of countries

Indicators	Africa CCVI Theme	Africa CCVI Subtheme	Relation to Africa CCVI
Percentage of women with access to newspaper, television and radio at least once a week	Socioeconomic Status	Access to information	Negative
Percentage of men with access to newspaper, television and radio at least once a week	Socioeconomic Status	Access to information	Negative
Percentage of households possessing a television	Socioeconomic Status	Access to information	Negative
Percentage of households possessing a mobile telephone	Socioeconomic Status	Access to information	Negative
Percentage of women who own a mobile phone	Socioeconomic Status	Access to information	Negative
Percentage of men who own a mobile phone	Socioeconomic Status	Access to information	Negative
Percentage of women with primary education	Socioeconomic Status	Education	Negative
Percentage of women with secondary or higher education	Socioeconomic Status	Education	Negative
Percentage of men with primary education	Socioeconomic Status	Education	Negative
Percentage of men with secondary or higher education	Socioeconomic Status	Education	Negative
Percentage of men with secondary or higher education	Socioeconomic Status	Education	Negative
Percentage of women who cannot read at all	Socioeconomic Status	Education	Positive
Percentage of women who are blind or visually impaired and unable to read	Socioeconomic Status	Education	Positive
Percentage of men who cannot read at all	Socioeconomic Status	Education	Positive
Multidimensional poverty index	Socioeconomic Status	Poverty	Positive
Percentage of women who did no work in the 12 months preceding the survey	Socioeconomic Status	Unemployment	Positive
Percentage of men who did no work in the 12 months preceding the survey	Socioeconomic Status	Unemployment	Positive
Population density per square km	Population Density	Population density	Positive
Population density at which the median individual lives in that region	Population Density	Population density	Positive
Percentage of households possessing a	Housing type &	Access to	Negative

motorcycle	Transportation	transportation	
Percentage of households possessing a private car	Housing type & Transportation	Access to transportation	Negative
Mean of road meters per km2 per cell	Housing type & Transportation	Connectivity	Negative
Mean number of household members	Housing type & Transportation	Crowding	Positive
Percentage of households with one room used for sleeping	Housing type & Transportation	Crowding	Positive
Mean number of persons per sleeping room	Housing type & Transportation	Crowding	Positive
Prevalence of improved housing in sub-Saharan Africa, in 2015	Housing type & Transportation	Housing	Negative
Percentage of households whose main source of drinking water is an improved source	Housing type & Transportation	Sanitation	Negative
Percentage of households with water on the premises	Housing type & Transportation	Sanitation	Negative
Percentage of households using an appropriate treatment method, including boiling, bleaching, filtering or solar disinfecting.	Housing type & Transportation	Sanitation	Negative
Percentage of households with a flush or pour flush toilet not to a sewer, septic tank or pit latrine	Housing type & Transportation	Sanitation	Negative
Percentage of households where a place for washing hands was observed	Housing type & Transportation	Sanitation	Negative
Percentage of households with water more than 30 minutes away round trip	Housing type & Transportation	Sanitation	Positive
Percentage of households with an unimproved sanitation facility	Housing type & Transportation	Sanitation	Positive
Percentage of households whose main type of toilet facility is no facility (open defecation)	Housing type & Transportation	Sanitation	Positive
HIV Prevalence 2000-2017: Mean Estimates	Epidemiological Factors	HIV Prevalence	Positive
Lower respiratory infection (LRI) prevalence among children under 5	Epidemiological Factors	Other infectious disease rates	Positive
Annual Mean of Parasite Rate (Plasmodium falciparum)	Epidemiological Factors	Other infectious disease rates	Positive
Percentage of women who are obese according to BMI (>=30.0)	Epidemiological Factors	Obesity	Positive
Percentage of men who are obese according to BMI (>=30.0)	Epidemiological Factors	Obesity	Positive
Prevalence of Diabetes	Epidemiological Factors	Diabetes	Positive
Prevalence of Hypertension	Epidemiological Factors	Hypertension	Positive

Percentage of men who smoke cigarettes	Epidemiological Factors	Smoking	Positive
Number of health sites (normalized to population)	Health System Factors	Health System Capacity	Negative
Percentage of women who had a live birth in the five (or three) years preceding the survey who received antenatal care during the pregnancy for the most recent live birth from a skilled provider	Health System Factors	Access to healthcare systems	Negative
Percentage of children with fever in the two weeks preceding the survey for whom advice or treatment was sought from a health facility or provider	Health System Factors	Access to healthcare systems	Negative
Percentage of live births in the five (or three) years preceding the survey delivered at a health facility	Health System Factors	Access to healthcare systems	Negative
Percentage of children born in the five (or three) years preceding the survey with diarrhea in the two weeks preceding the survey who were taken for a treatment to a healthy facility	Health System Factors	Access to healthcare systems	Negative
Percentage of women who reported they have big problems in getting money for treatment for themselves when they are sick	Health System Factors	Access to healthcare systems	Positive
Percentage of women who reported they have big problems in the distance to health facility for treatment for themselves when they are sick	Health System Factors	Access to healthcare systems	Positive
Percentage of children 12-23 months who had received no vaccinations	Health System Factors	Vaccination	Positive
Number of population of concern sites (normalized to population)	Fragility	UNHCR population of concern sites	Positive
Number of deaths in armed conflicts (normalized to population)	Fragility	Civil Unrest	Positive
Number of battles occurrences since Jan 1, 2020	Fragility	Civil Unrest	Positive
Number of explosions occurrences since Jan 1, 2020	Fragility	Civil Unrest	Positive
Number of violence against civilians incidences since Jan 1, 2020	Fragility	Civil Unrest	Positive
Number of riots occurrences since Jan 1, 2020	Fragility	Civil Unrest	Positive
Percentage of children stunted (below -2 SD of height for age according to the WHO standard)	Fragility	Food insecurity	Positive
Percentage of children under age 5 classified as having any anemia	Fragility	Food insecurity	Positive
Percentage of women classified as having	Fragility	Food insecurity	Positive

any anemia (<12.0 g/dl for non-pregnant women and <11.0 g/dl for pregnant women)			
Percentage of men classified as having any anemia	Fragility	Food insecurity	Positive
Percentage of households with 3 generations	Old Age	Old Age	Positive
Percentage of population 60 years or older	Old Age	Old Age	Positive

Appendix 2: Age of main data sources per country

Country	Data Year	Main Data Source
Angola	2006-2015	DHS
Burundi	2010-2016	DHS
Benin	2006-2017	DHS
Burkina Faso	2003-2017	DHS
Côte d'Ivoire	2012	DHS
Cameroon	2004-2011	DHS
Democratic Republic of Congo	2007-2013	DHS
Republic of Congo	2011	DHS
Comoros	2012	DHS
Egypt	2003-2014	DHS
Eritrea	2002	DHS
Ethiopia	2011-2016	DHS
Gabon	2012	DHS
Ghana	2003-2016	DHS
Guinea	2012-2018	DHS
Gambia	2013	DHS
Kenya	2008-2014	DHS
Liberia	2013	DHS
Lesotho	2009-2014	DHS
Morocco	2003	DHS
Madagascar	2004-2008	DHS
Mali	2006-2018	DHS
Mozambique	2009-2018	DHS
Mauritania	2000	DHS
Malawi	2010-2015	DHS
Namibia	2000-2013	DHS
Niger	2006-2012	DHS
Nigeria	2013-2018	DHS
Rwanda	2008-2017	DHS
Senegal	2005-2017	DHS
Sierra Leone	2008-2016	DHS
Eswatini	2006	DHS
Chad	2014	DHS
Togo	2013-2017	DHS
Tanzania	2004-2017	DHS
Uganda	2011-2018	DHS
South Africa	2016	DHS
Zambia	2007-2018	DHS

Zimbabwe	2010-2015	DHS
Libya	2014	Open Data for Africa, MICS
Somalia	2011	Open Data for Africa, MICS
South Sudan	2010	Open Data for Africa, MICS
Sudan	2014	Open Data for Africa, MICS
Tunisia	2018	Open Data for Africa, MICS
Central African Republic	2010	Open Data for Africa, MICS
Djibouti	2007	Open Data for Africa, MICS
Algeria	2012	Open Data for Africa, MICS

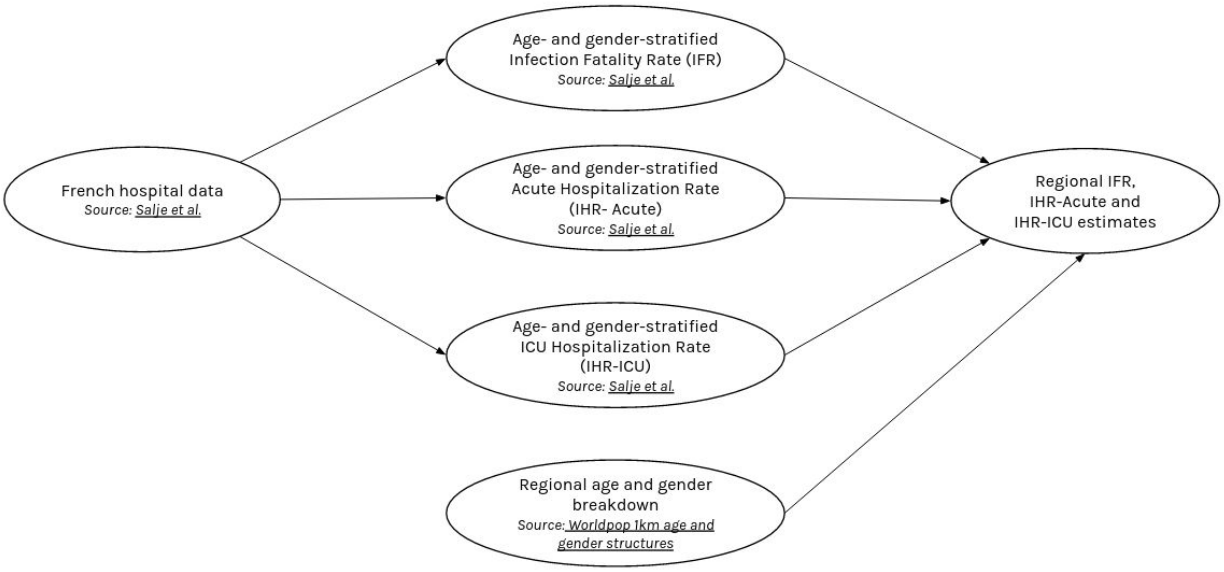
Appendix 3: difference with US CCVI

The US CCVI uses the US Centers for Disease Control and Prevention's (CDC) Social Vulnerability Index (SVI). The SVI ranks communities on susceptibility to any type of disaster, using data across four themes: socioeconomic status, household composition and disability, minority status and language, and housing type and transportation. We added two COVID-19-specific themes - epidemiological factors and health-system factors - that have been shown to compound effects of the virus in Italy and the United States. To make it more relevant to the African context and account for the negative effects of armed conflicts or the presence of refugee camps, we added a theme Fragility. We also removed the minority status and language theme, because of the lack of publicly available data on minority populations and languages at administrative-one level. Theme 4, epidemiological factors, was expanded to include indicators that capture prevalence of epidemiological factors relevant to Africa, including malaria and HIV. Similarly, Theme 3, housing type and transportation, was modified to include indicators on access to clean water and basic sanitation. Finally, we removed old age from Theme 4 and moved it to a separate theme, given the enormous health risk posed by COVID-19 to the elderly.

Appendix 4: Calculating Hospitalization Rate (IHR-Acute)

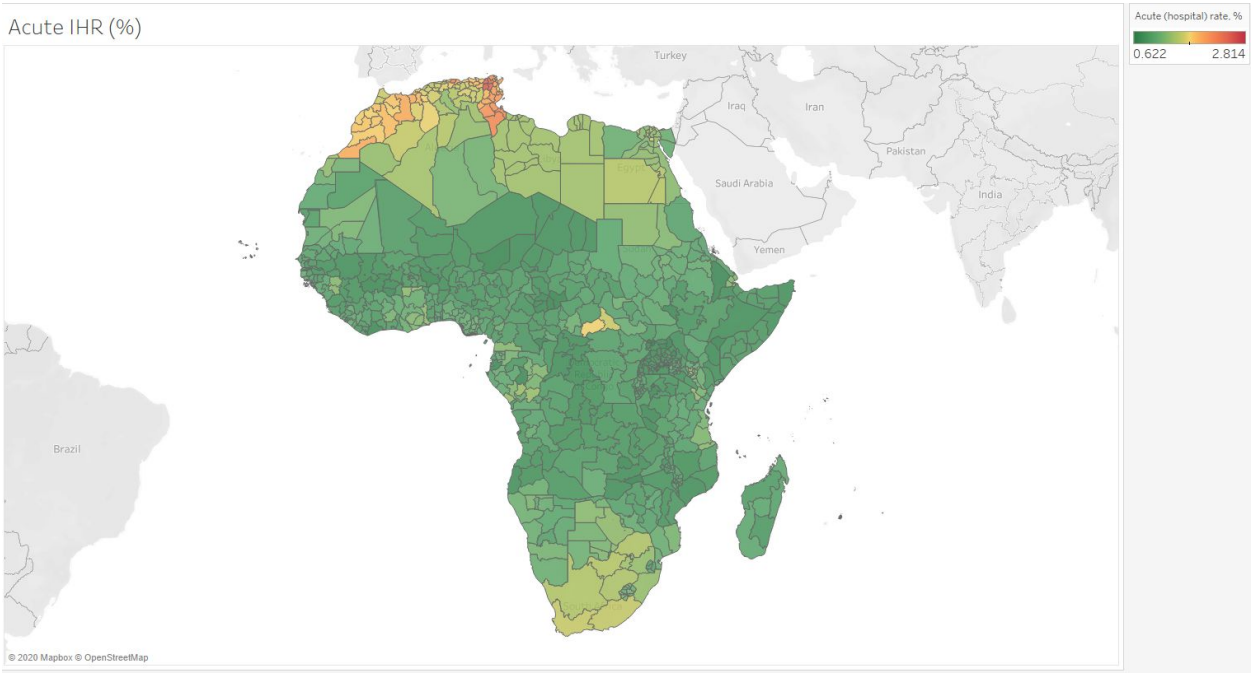
Salje et al. estimated age- and gender- stratified Infection Fatality Rate (IFR), Hospitalization Rates (IHR-Acute), and ICU Hospitalization Rates (IHR-ICU) based on data collected in France. These estimates predicted rates of fatality and hospitalization from COVID-19 for different age and gender groups.

We calculated IHR-Acute (% of infected people that require care) by combining age/sex-stratified hospitalization rates from the Salje manuscript with World Pop estimates of age and sex structures per square kilometer to generate regional, population-weighted estimates of IHR (see figure). Though we calculated the IFR as well using this method, we only show the IHR-Acute on the website, as we identified a better way of calculating the IFR (Appendix 5). The IHR-Acute is particularly critical as it represents the predicted *need* for care, unaffected by the availability of care.



The resulting IHR-Acute are based on the French population, with corresponding rates of comorbidities. If African countries have a different pattern of comorbidities relevant to COVID-19, the projected IHR might not be accurate. We find that compared to France, countries in Sub-Saharan Africa tend to have higher rates of COVID-19-relevant comorbidities among their younger and middle-aged residents, but similar rates of comorbidities amongst their older residents (Clark et al.). For example, comorbidity rates for French citizens aged 20-24 are estimated at 7%, while they are estimated at 16% for residents of South Africa.

Because our calculations of Infection Hospitalization Rates (IHR) for Africa assume similar rates of comorbidities to France, and because individuals with comorbidities tend to be hospitalized at higher rates, our IHR likely slightly underestimates hospitalization rates among younger age bands throughout Africa.



Appendix 5: Calculating Infection Fatality Rate (IFR)

Our initial analysis of IFR and IHR rates for different regions of Africa (Appendix 4) came with important caveats. First, the estimated rates were based on French outcomes, where health systems are much stronger than in most African countries. A weaker health system would drive up the infection fatality rate (IFR). Further, the rates assumed that individuals in different countries had similar levels of comorbidities to patients in France. Comorbidities can also drive up the IFR. Finally, the rates assumed that everyone is equally likely to be infected, so do not take into account lockdowns or shielding.

We calculated adjusted IFRs based on work by the Center for Global Development (CDG; see table from report below). The CDG paper stratified IFR and hospitalization by age, gender, comorbidities, and health system capacity (estimated for each World Bank income designation).

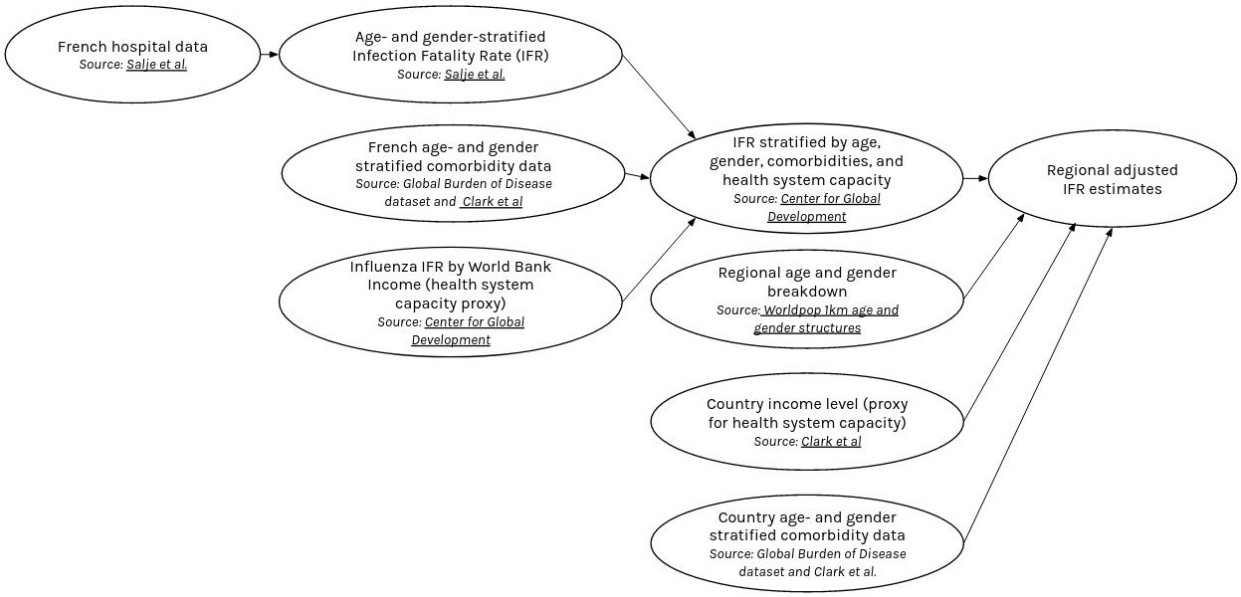
	LIC and LMIC				UMIC				HIC			
	Female		Male		Female		Male		Female		Male	
Comorb.	0	>0	0	>0	0	>0	0	>0	0	>0	0	>0
Age												
0-9	0.0003	0.2503	0.0003	0.2723	0.0002	0.1598	0.0002	0.1747	0.00004	0.0361	0.00004	0.0397
10-19	0.0003	0.2503	0.0003	0.2723	0.0002	0.1598	0.0002	0.1747	0.00004	0.0361	0.00004	0.0397
20-29	0.0015	0.3618	0.0022	0.6373	0.0009	0.2333	0.0015	0.4149	0.0002	0.0534	0.0003	0.0963
30-39	0.0059	0.8927	0.0085	1.3225	0.0039	0.5838	0.0057	0.8786	0.0009	0.1364	0.0014	0.2100
40-49	0.0121	1.1383	0.0203	1.7715	0.0081	0.7627	0.0139	1.2155	0.0020	0.1847	0.0035	0.3057
50-59	0.0606	3.4417	0.0900	3.8320	0.0426	2.4215	0.0657	2.7985	0.0112	0.6353	0.0185	0.7865
60-69	0.1930	5.4668	0.4135	7.4889	0.1456	4.1251	0.3278	5.9360	0.0438	1.2395	0.1105	2.0008
70-79	0.6169	8.4323	1.3529	12.3723	0.4971	6.7946	1.1504	10.5207	0.1749	2.3906	0.4755	4.3483
80+	3.0601	20.1473	7.9923	43.7599	2.6109	17.1896	7.1846	39.3374	1.0913	7.1848	3.6682	20.0846

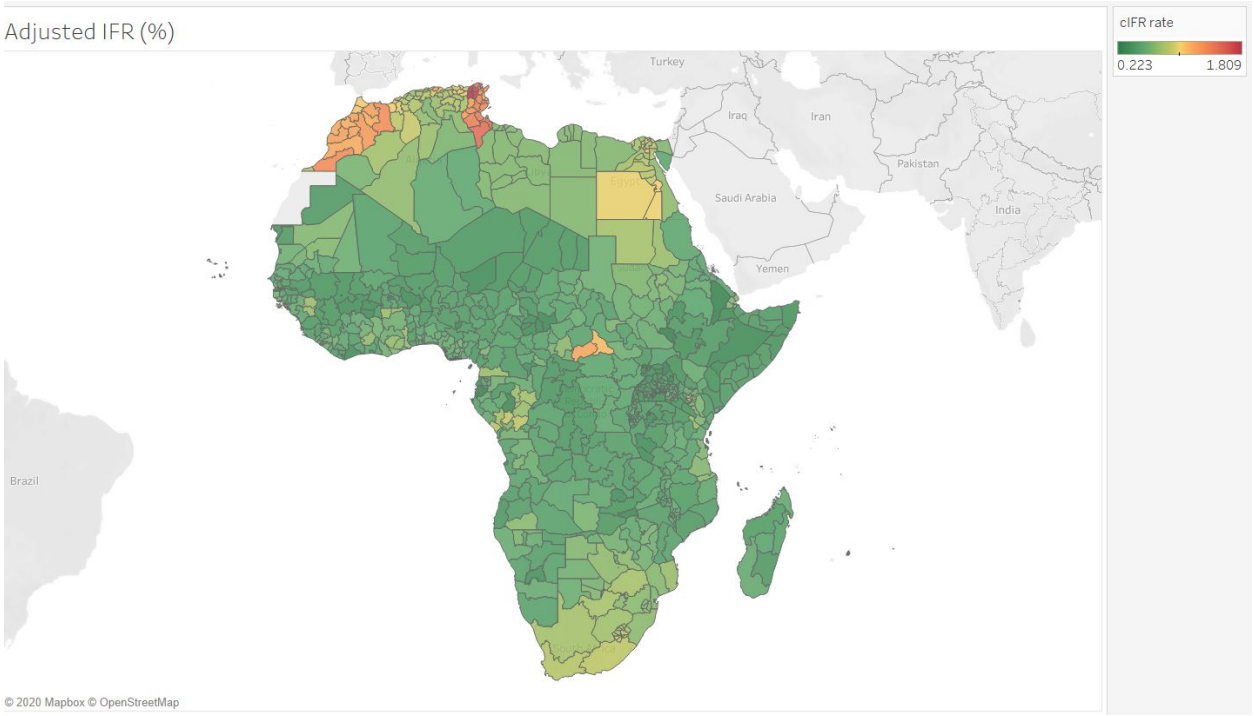
For each region in our dataset, we recalculated age- and gender- stratified IFRs based on the following information (see figure below):

1. World Bank Income status (country-level)
2. Presence of COVID-19 comorbidities, stratified by age and gender(country-level).

To obtain #2, we used the country-level estimates of COVID-19 risk factors calculated by Clark et al. who estimated the age- and gender- stratified presence of COVID risk factors for each country. These estimates were derived from the 2017 Global Burden of Disease dataset. We used Clark's mid-level estimates of presence of at least one COVID-19 risk factor ('analysis' sheet of Clark's supplementary Excel file, lines 1218-1260) to estimate the age- and gender-stratified rates of comorbidities at the country level.

Finally, we used these data to estimate regional IFRs. We used the Country-level World Bank designations to determine which IFR rates to use from the CGD-adjusted IFR table. Regional IFR estimates were weighted by age, gender, and presence of comorbidities.




Adjusted IFR (%)
cIFR rate
0.223
1.809
Turkey
Iraq
Iran
Pakistan
Saudi Arabia
India
Yemen
Brazil
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