Identification of Vulnerable Areas of High COVID-19 Mortality Risk in Ohio
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Introduction
Early Coronavirus (COVID-19) disease data from Europe and Asia suggested unprecedented contagious and death rates of the pandemic. In late April, the United States (U.S.) exhibited the fastest growing curve in terms of COVID-19 related deaths across developed countries, with 93,806 deaths as of May 20th. Several countries, including the U.S., have reported higher mortality rates for older individuals with concomitant comorbidities, including chronic lower respiratory diseases, diabetes, hypertension, and ischemic diseases. Likewise, health-related disparities including sociodemographic and environmental factors have been identified as important drivers of deaths caused by COVID-19. Identification of groups and areas which have a higher risk of mortality due to COVID-19 related complications is the logical next step for policy makers to address the pandemic.

Using COVID-19 data obtained from the Johns Hopkins University dataset¹ for 3,045 counties across the U.S. up to May 05, 2020, we conducted a Bayesian multilevel analysis to assess the risk of COVID-19 related deaths per state and county, adjusting for sociodemographic, health and environmental factors. Our analysis presented below focuses primarily on the state of Ohio. The aims of our analyses are to identify: 1) counties at high risk of COVID-19 related mortality, and 2) counties with a high mortality risk and a low healthcare capacity in Ohio.

Identification of counties with high COVID-19 related mortality risk in Ohio
Our analysis focuses on the state of Ohio. However, we used data from the entire country to conduct state comparisons between Ohio and the rest of the country, and to derive reliable estimations for the state. We conducted a Bayesian multilevel analysis to assess the risk of COVID-19 related death by county, adjusting for sociodemographic, health, and environmental factors. We found that eight states had higher COVID-19 related mortality risk than expected (Colorado, Connecticut, Indiana, Massachusetts, Michigan, Louisiana, New Jersey, and Washington). According to our results, Ohio does not have a higher COVID-19 related mortality risk than expected, and the COVID-19 related mortality risk in the state is consistent with the expected mortality risk according with the number of residents in Ohio. In contrast, Indiana and Michigan hold the highest risk for the Midwest region with a relative risk of 2.68 and 2.70, respectively.
Although Ohio does not have a higher COVID-19 related mortality risk than the country average, we found substantial differences in the mortality risk between counties in Ohio. The map in the left in Figure 1 illustrates the cumulative number of COVID-19 related deaths by county in Ohio as of May 5, 2020. The map in the right illustrates the estimated COVID-19 related mortality risk. Even though Cuyahoga, Franklin, and Hamilton counties have the highest cumulative number of COVID-19 related deaths, their COVID-19 related mortality risk is lower than expected based on the total population of these counties. Conversely, counties like Allen, Ashtabula, Columbiana, Darke, Geauga, Lucas, Mahoning, Miami, Pickaway, Portage, Putnam, Stark, Trumbull, Washington, Wayne, and Wood have a higher than average COVID-19 related mortality risk than would be expected from their populations.

**Figure 1. Spatial distribution of the cumulative number of COVID-19 related deaths (Left) and COVID-19 related mortality risk (Right) in Ohio**

**Vulnerable counties with high COVID-19 mortality risk but low healthcare capacity in Ohio**

We generated a map to visualize the association between COVID-19 related mortality risk and the healthcare capacity of each county in Ohio. For the purpose of our analysis, healthcare capacity was estimated as number of ICU beds available under normal circumstances (Figure 2). Mortality risk (red color) was classified as follows: 0-1 indicates lower risk, 1-1.5 indicates medium risk, and > 1.5 indicates high risk. ICU beds availability (blue color) was classified as follows: < 40 ICU beds indicates low availability, 40-100 ICU beds indicates medium availability, and > 100 ICU beds indicates high availability. Counties in dark red indicate high mortality risk and low ICU bed availability, whereas counties in dark blue indicate high ICU bed availability and low mortality risk. Darke, Miami, Pickaway, Washington, Allen, Putnam, Wayne, Portage, Mahoning and Columbiana are the most vulnerable counties, with high risk of COVID-19 related death and a low healthcare capacity as estimated as availability of ICU beds.
Figure 2. Bivariate map of COVID-19 related mortality risk and ICU availability in Ohio

**Recommendations**

Our results suggest that COVID-19 related mortality in Ohio is consistent with the expected deaths based on the total population of the state. However, there is substantial variation on the COVID-19 related risk of mortality among counties in Ohio. Although the population of most of the counties have low risk of dying for COVID-19 related complications, we found that in counties like Allen, Columbiana, Darke, Lucas, Mahoning, Miami, Pickaway, Portage, Putnam, Washington, and Wayne the risk of dying for COVID-19 related complications is almost twice as high compared to the other counties in the state. These counties are experiencing an excess of COVID-19 related deaths potentially driven by socioeconomic and environmental factors that are exacerbating COVID-19 related mortality in the population residing in these areas. These counties are also vulnerable areas with low healthcare capacity response. Therefore, these counties are high priority areas where healthcare capacity needs to be expanded to reduce COVID-19 related deaths as the pandemic progress in the coming months.
Appendix: Methods and References

The study area focuses in the state of Ohio. However, we used data from the entire U.S to conduct state comparisons between Ohio and the rest of the country, and to derive reliable estimations for the state. COVID-19 data were derived from the Johns Hopkins University dataset \(^1\) for 3,045 counties from 50 states (excluding the state of NY). We conducted a Bayesian multilevel analysis to assess the risk of COVID-related death per county, adjusting for sociodemographic, health, and environmental factors including\(^2\): percent estimate for total population by age-groups (Under 25, 25-34, 35-44, 45-59, 60-74, and over 75) by county, percent estimate for total population of White, Black, and Hispanic or Latino by county according to the Census Bureau definition\(^6\), and percentage estimate of persons below poverty according to the CDC’s vulnerability index\(^3\). For county-level underlying cause of death, we selected four chronic conditions: chronic lower respiratory disease, diabetes mellitus, hypertension, and ischemic heart disease mortality rates per 100,000 people in each county\(^7\). Air Pollution was included using the Surface annual PM 2.5 satellite images from 2000 to 2018\(^5\).

Using this model, we generated a small area disease risk map after adding State-level random intercepts. Small area risk estimates were generated by computing the adjusted relative risk (RR) for each county. The RR for county \(i\) was calculated as the ratio of observed \((Y_i)\) to the expected disease counts \((E_i): RR_i = Y_i / E_i\), where the expected counts represented the total number of COVID-related deaths based on the population of the county \(i\). A Poisson distribution was used to avoid extreme values due to areas with small populations counties with RR equal to 1 have the same mortality risk as expected based on the total population of the county. Counties with RR less than 1 may be an indicative of counties with lower mortality risk than expected, and a RR greater than 1 indicates higher mortality risk.

References