RESEARCH ARTICLE

# A Comparison of COVID-19 Epidemiology, Pathophysiology, and Impact on Vulnerable Populations in Two States within the USA

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**Abstract**

Since late 2019, SARS-CoV-2 has differentially impacted geographies and population demographics as it spread. As of June 30, 2020, two hotspots within the United States of America—the states of Georgia and Michigan—exhibited similar numbers of cases while Michigan had over twice the case fatality rate (CFR) of Georgia. Given the similar populations, land areas, and pandemic timelines of these states, such a large difference is unexpected. The primary goal of this paper is to examine why Michigan experienced much higher COVID-19 mortality than Georgia, which may point to at-risk comorbidities and vulnerable populations.

We examined publicly available data on demographics, rates of comorbidities, environmental factors, and other population differences at the state and local levels (the cities of Detroit, Michigan; Atlanta, Georgia; and Albany, Georgia) that have known or identified associations with health outcomes. We also outlined the timeline of the pandemic in each state to determine if the actions of state governments may have contributed to the observed difference in CFR.

While the difference in state CFR may imply that Michigan handled the pandemic poorly, the data show that inherent characteristics of Detroit may have led to the higher statewide CFR. Notable differences between the states include elderly populations, agricultural statistics, and drinking habits. Notable differences between the cities included population density, health system quality, per capita income, race, education, media access, and air pollution. Hypertension (among blacks), diabetes (at the city level), chronic kidney disease, asthma, heart disease, and cancer differed in prevalence by location and were associated with increased severity and/or mortality of COVID-19. There were more deaths due to COVID-19 in African American communities and nursing homes in Michigan. A combination of these factors likely explains the differential impact between these two states.

# 1 Introduction

## 1.1 Pathophysiology

Severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) originated from a seafood market in Wuhan, China via zootomic transmission in late 2019. COVID-19, the disease caused by this novel coronavirus, has since spread around the globe. Coronaviruses are a family of single-stranded RNA viruses that are enveloped and positive-sense.[1,2] They can invade many hosts and are divided into four genera: α, β, γ, and δ.[1] Of these, only α and β infect mammals, causing mild to moderate upper respiratory tract illnesses. [1,3,4] However, SARS-CoV-2 specifically can cause lower respiratory tract infections with more severe outcomes.[3] While more common symptoms include fever, cough, and shortness of breath, individuals may portray a wide spectrum of symptoms affecting many organ systems. This variation in illness presentation, along with the opportunity for viral transmission via asymptomatic individuals, make the novel coronavirus a uniquely dangerous public health concern.

Similar to other coronaviruses, SARS-CoV-2 attaches itself to the host cell, penetrates the cell via endocytosis or membrane fusion, and replicates its RNA to make viral proteins.[1] Though coronaviruses have 4 structural proteins (Spike, membrane, envelope, and nucleocapsid), Spike (S) determines diversity, host response, and binding and fusion of the two membranes.[1,4] Studies have identified that the angiotensin-converting enzyme II (ACE2) receptor facilitates SARS-CoV-2 entry into target cells.[6,7] The potential multi-system effects of SARS-CoV-2 may be explained in part by the presence of ACE2 receptors in many different body tissues. SARS-CoV-2's viral entry via ACE2 receptors also utilizes transmembrane protease, serine 2 (TMPSSR2) to assist with priming the spike (S) protein, which allows for fusion between the viral and cellular membranes.[7]

Initial studies on host responses to novel coronavirus suggests that a cytokine storm may correlate with greater COVID-19 severity. Infected patients have displayed elevated proinflammatory serum cytokines, and those requiring ICU admission may display even higher levels of specific proinflammatory serum cytokines (GCSF, IP10, MCP1, MIP1A, and TNFα) than patients who do not require admission.[8] Production of IL-6 and IL-8 by infected epithelial cells accounts for this decrease; IL-8 is known as a chemoattractant to neutrophils and T cells, both of which can cause injury to the lung.[1]

## 1.2 Purpose

The current COVID-19 pandemic has proven that globalization, which has physically and virtually connected individuals around the world more than ever before, has disadvantages. This increased connectivity has allowed the novel coronavirus to differentially impact countries, states, and local communities. Since the pandemic began in the United States in January 2020, the country has exhibited a spectrum of coronavirus impacts (cases and deaths) and responses across individual states.

In this paper, we will examine two states in the US—Georgia and Michigan—that have surprising differences in COVID-19 statistics. As of June 30, 2020, these states possessed a similar number of positive COVID-19 cases: 81,291 in Georgia and 70,728 in Michigan. Nonetheless, Michigan displayed a total COVID-19 case fatality rate (CFR) of 8.76%, over two times Georgia's rate of 3.45%.[9] Local hotspots within these states include the cities of Atlanta and Albany in Georgia and Detroit in Michigan. On June 30, the Atlanta-Sandy Springs-Alpharetta

Metropolitan Statistical Area* ("Atlanta MSA") had 38,469 cases with a CFR of 3.64%. The Albany MSA** had 2,831 cases with a CFR of 7.95%. The Detroit-Warren-Dearborn MSA*** ("Detroit MSA") had 43,565 cases with a CFR of 11.10%.[9] To attempt to explain these varying CFRs, this paper will outline similarities and differences between these states and the cities within.

Ultimately, this study aims to explore the pathophysiological, sociodemographic, and environmental factors that may have contributed to the difference in the epidemiology of COVID-19 between Georgia and Michigan. We aim to explore the pandemic's initial progression from January, 2020 through June, 2020 in both of these states. While the disease situation is constantly evolving, we set the cut off in June, covering the first five months of the pandemic. This study will investigate topics including demographics, pandemic-response timelines, comorbidities within the population, and vulnerable subpopulations. We anticipate that a better understanding of such contributing factors will encourage greater healthcare availability and outreach for vulnerable populations, guide pandemic response and infection control and ultimately reduce COVID-19 pandemic-associated mortality.

*The Atlanta MSA includes 29 counties in the area around the city border.

**The Albany MSA includes 4 counties in the area around the city border.

***The Detroit MSA includes 6 counties in the area around the city border.[10]

### 1.3 Methods

Initial identification and selection of Georgia and Michigan as comparison states was based on data collected by Johns Hopkins University related to case rates and death rates of COVID-19. Both states shared similar case rates, populations, and a combination of urban and rural areas, but differed greatly in the number of COVID-19 deaths. Following selection, data on COVID-19 cases and deaths were collected from each state and some cities in each state, the most populous and most highly impacted cities.

The rest of the review investigates potential factors explaining the difference between the deaths. Risk factors for COVID-19 were identified from news reports and studies, and included population demographics, policy decisions, pre-existing conditions, and vulnerable populations. Data for these factors was collected from government databases and organized in this review. Differences in the completeness and time of collection in the datasets prevented statistical analysis. Significant differences were identified qualitatively when apparent.

## 2 Comparison of States

### 2.1 COVID-19 Impact in States

**Table 1: COVID-19 related statistics in Michigan and Georgia, as of June 30, 2020**[9]

| State/City | Cases | Cases/100,000 | Deaths | Deaths/100,000 | CFR (%) |
|---|---|---|---|---|---|
| Michigan[9,11] | 70,728 | 708 | 6,193 | 62 | 8.76 |
| Detroit-Warren-Dearborn MSA[9,12] | 43,565 | 1,009 | 4,836 | 112 | 11.10 |
| Grand Rapids-Kentwood MSA*[9,12] | 6,519 | 605 | 190 | 18 | 2.91 |
| Flint MSA**[9,12] | 2,734 | 674 | 288 | 71 | 10.53 |
| Georgia[9,11] | 81,291 | 766 | 2,805 | 26 | 3.45 |
| Atlanta-Sandy Springs-Alpharetta MSA[9,12] | 38,469 | 639 | 1,400 | 23 | 3.64 |
| Metro Augusta***[9,13] | 1,695 | 413 | 71 | 17 | 4.19 |
| Albany MSA[9,12] | 2,831 | 1,827 | 225 | 145 | 7.95 |

*Grand Rapids-Kentwood MSA includes 4 counties in the areas of the two cities.
**Flint MSA includes Genessee County, the seat of the city.
***Metro Augusta includes 5 counties in the area around the city.[10]

### 2.2 Overall Demographics/Table

**Table 2: Various Population Measurements in Michigan and Georgia**

| Measurement | Michigan | Georgia |
|---|---|---|
| 2019 Population[11] | 9,986,857 | 10,617,423 |
| People 65 Years of Age and Older (%)[11] | 17.7 | 14.3 |
| Income per Capita (USD)[11] | 30,336 | 29,523 |
| Black (%)[11] | 14.1 | 32.6 |
| White (%)[11] | 79.2 | 60.2 |
| Estimated Direct Agricultural Jobs* in 2019[14] | 61,800 | 42,100 |
| Crop Sales (in billions of USD)[15] | 4.64 | 3.27 |
| Staffed Hospital Beds per 1,000 People[16] | 2.5 | 2.4 |
| Population per Bar[17] | 6,104 | 21,812 |
| Prevalence of Binge Drinking Among Adults (%)[18,19] | 19.5 | 16.1 |

*"Direct agricultural jobs" excludes other industries that are related to agriculture such as manufacturing, food retail and wholesale.

Michigan has a higher percentage of people 65 years of age and older, a population associated with increased COVID-19 mortality.[20] Michigan also has a higher number of direct agricultural jobs than Georgia, which may expose these employees to pesticides, herbicides, and fertilizers and other chemicals that may be harmful to lung and overall health. Michigan has more crop sales, the portion of agriculture that deals more with aerosolized chemicals (as opposed to animal farming), than Georgia.

Additionally, there are many more bars in Michigan than Georgia compared to the populations. Attendance at these bars prior to shelter-in-place orders may have contributed to the virus' rapid more spread in Michigan. Finally, people in Michigan report higher levels of binge-drinking among adults. Binge drinking has been linked to cirrhosis and fatty liver.[21,22] The Centers for Disease Control and Prevention (CDC) reported that in 2018, the chronic liver disease/cirrhosis death rate in Georgia was 9.9 versus 10.7 in Michigan.[23] COVID-19 has been linked to liver damage in multiple ways, putting Michigan at greater risk due to increased binge drinking.[24]

### 2.3 Impacted Cities

We examined statistics for the relevant MSAs and the cities proper to better understand factors that may have contributed to the observed differences in CFR.

**Table 3: Various Population Measurements in Detroit, Atlanta, and Albany**

| Measurement | Detroit | Atlanta | Albany |
|---|---|---|---|
| Population Density (ppl/mi$^2$)[25-30] | 1,104 (MSA)<br>4,831 (city) | 719 (MSA)<br>3,740 (city) | 214 (MSA*)<br>1,289 (city) |
| Income per Capita (USD)[31,32] | 53,086 (MSA)<br>17,338 (city) | 52,473 (MSA)<br>43,468 (city) | 37,500 (MSA)<br>19,579 (city) |
| Black (%)[32,33] | 22.3 (MSA)<br>78.6 (city) | 34.3 (MSA)<br>51.8 (city) | 53.9 (MSA)<br>73.5 (city) |
| White (%)[32,33] | 69.2 (MSA)<br>14.6 (city) | 52.8 (MSA)<br>40.3 (city) | 40.7 (MSA)<br>22.7 (city) |
| Population over 25 with at least a High School Diploma (%)[32,34] | 90.2 (MSA)<br>80.0 (city) | 90.1 (MSA)<br>90.3 (city) | 82.8 (MSA)<br>81.7 (city) |
| Average Max Annual Temperature (°C) | 14.4 | 22.5 | 25.8 |
| Average Min Annual Temperature (°C)[35] | 6.0 | 10.7 | 12.9 |
| Average Annual Morning Relative Humidity (%) | 80 | 81 | 82 |
| Average Annual Morning Relative Humidity (%)[36,37] | 59 | 55 | 55 |
| Households without Broadband Internet (%)[38,39] | 22.1 (MSA)<br>29.7 (city) | 17.7 (MSA)<br>13.1 (city) | --<br>24.4 (city) |
| Households without Cable (%)[39] | 52.1 (city) | 29.3 (city) | 50.1 (city) |
| 2019 Enplanements[40] | 18,143,040 | 53,505,795 | 41,268 |
| Frequently or Regularly Attend Religious Services (%)*[41] | 51.02 (Wayne) | 49.33 (Clayton) | 59.55 (Terrell) |
| $PM_{2.5}$ Weighted Annual Mean (µg/m$^3$)** | 12.1 (Wayne) | 10.8 (Gwinnett) | 9.3 (Dougherty) |
| $PM_{2.5}$ 24-h 98$^{th}$ Percentile (µg/m$^3$)[42] | 31 (Wayne) | 24 (Gwinnett) | 26 (Dougherty) |

*At the time the population data was estimated, the definition of the Albany MSA included an additional county.
**The highest county value in the metro region of the city is shown.

For both the MSAs and cities, the population density of Detroit was highest, which suggests that social distancing was more difficult. Inside city bounds, the income per capita was much lower in Detroit and Albany than in Atlanta. Within the city, Detroit and Albany had a higher percentage of the population that was African American than Atlanta. Detroit and Albany (cities) also had lower percentages of adults over 25 with at least a high school diploma. In a large and comprehensive statistical analysis, Xiao Wu et al. found increased COVID-19 mortality associated with all four of these factors, indicating they all likely contributed to the higher CFR in Detroit.[20]

Moreover, the particulate matter 2.5 ($PM_{2.5}$) concentrations were highest in Detroit in 2019. Acute and chronic exposure to high concentration of these fine particles in the air has been associated with increased cardiovascular, respiratory and all-cause mortality.[43,44] More specifically, Xiao Wu et al. found an 8% increase in COVID-19 mortality for each 1μg/$m^3$ increase in average long-term (2000-2016) $PM_{2.5}$ levels in 3,087 counties (98% of the population) in the US.[20] These findings suggest that higher levels of fine particle air pollution in Detroit contributed to its higher CFR.

Yu Wu et al. found that across 166 countries, each increase in 1°C resulted in a 3.08% reduction in daily new cases and a 1.19% reduction in daily new deaths.[45] Thus, higher average temperatures in Atlanta and Albany could have decreased the CFR. Finally, a higher percentage of households in Detroit lack access to broadband internet or cable. This difference may have made it harder for individuals in Detroit to be informed about the latest pandemic updates and recommendations. These data are summarized in Table 2 above.

### 2.4 Health Systems Comparison

Using the CDC WONDER database, age-adjusted rates of mortality per 100,000 people in 2018 for Georgia and Michigan were 790.2 and 782.3, respectively.[46] The crude mortality rate per 100,000 people was 809.9 in Georgia and 989.4 in Michigan. The average older age in Michigan may account for this discrepancy. Detroit, MI had an age-adjusted mortality rate of 790.3 (average across six counties). Atlanta, GA had an average age-adjusted rate of mortality of 611.8 (average across ten counties). For Albany, GA (Dougherty County) the age-adjusted rate of mortality was 948.9.

Based on the CDC WONDER database, the infant mortality rate per 1,000 in Georgia and Michigan was 7.18 and 6.78, respectively. Data was only available for some counties. Wayne County (Detroit) had an infant mortality rate of 10.44. Infant death rates in Atlanta counties were lower, with Fulton County at 5.46, Dekalb County at 8.14, and Gwinnett County at 6.03. Both these data and the age-adjusted rate of mortality suggest that, while both states have similar healthcare system efficacy, the Detroit area has a less effective healthcare system than Atlanta.

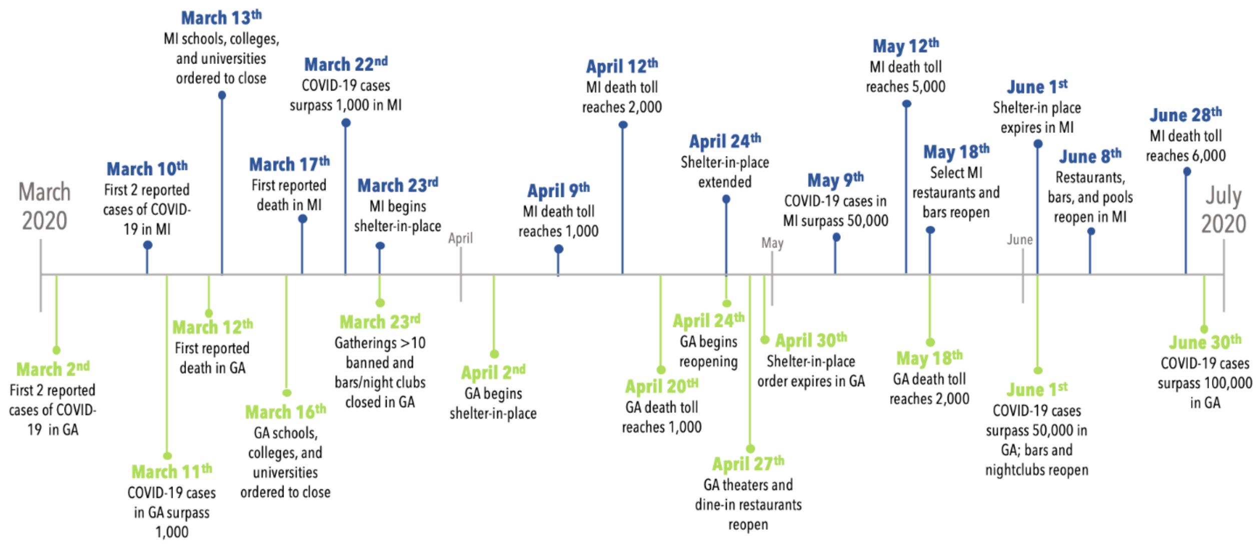
The 2018 National Healthcare and Disparities Report lists the quality of care found in both Georgia and Michigan in the 3rd quartile when ranked amongst the other states (1st quartile being the best); however, the state snapshots synthesized using data from the report more accurately describe the quality differences between the two states.[47] Michigan fell "far away from benchmark" on 26 of the achievable healthcare quality benchmarks, was deemed close to the benchmarks on 50, and achieved or surpassed the on 56 of the metrics. In comparison, Georgia fell well short on 34 benchmarks, was deemed close to the benchmarks on 42, and achieved or surpassed 56 of the benchmarks.[48,49]

Georgia has a much larger portion of its population that is uninsured than Michigan: about 1,411,000 or 13.7% of GA's population as compared to 535,000 or 5.4% of MI's population.[50] As of 2019, Atlanta was estimated to have an uninsured rate of 12.4%, Albany's rate was estimated at 20.1%, and Detroit's rate was estimated at 11.1%.[32]

## 3 Pandemic Timeline

### 3.1 Timeline Figure

**Figure 1: COVID-19 timeline with Michigan above and Georgia below**




### 3.2 Initial Cases

The first cases of COVID-19 in Georgia and Michigan were detected in early March 2020. The first reported COVID-19 cases in Georgia were on March 2, 2020: a father and son living in Fulton County (Atlanta).[51,52] The first reported cases in Michigan were on March 10, 2020.[53] One was a woman from Oakland County (part of metropolitan Detroit), and the other was a man from Wayne County (Detroit's county seat).[54]

### 3.3 Shelter in Place

On March 14, 2020, Governor Kemp of Georgia declared a public health state of emergency due to COVID-19.[55] On March 23, 2020, businesses such as bars, restaurants and theaters were closed, and gatherings of more than 10 were banned. This executive order also included Georgia's first shelter in place order, which only applied to people over the age of 65, people in nursing homes, and people with certain chronic diseases.[56] On April 2, 2020, this shelter in place order was extended to the entire state.[57] On April 30, 2020, Governor Kemp only renewed the shelter in place order for vulnerable populations, allowing the general shelter in place order to expire.[58]

On March 10, 2020, Governor Whitmer of Michigan declared a state of emergency in Michigan.[59] A few days later, gatherings of more than 250 were banned—a limit that was lowered to 50 people on March 17, 2020.[60,61] On March 16, 2020, public schools and businesses were closed, and on March 21, 2020, non-essential medical procedures were banned.[61,62] In the following days, Governor Whitmer issued a stay at home order, effective March 24, 2020, which required individuals to suspend activities that were not necessary to sustain or protect life.[63] One month later, an executive order was issued which extended the stay at home order. Violators of the order could face a misdemeanor charge.[64]

Based on the above information, it is unlikely that the statewide response to COVID-19 would be responsible for Michigan's higher death rate. Compared to Georgia, Michigan closed its public schools at the same time, was faster to close its businesses, and faster to issue a stay at home order.

### 3.4 Phases of Reopening

Georgia was the first state to reopen in the United States. Beginning on Friday, April 24, 2020, gyms, fitness centers, bowling alleys, tattoo parlors, hair salons, nail salons, and massage establishments reopened. This statewide measure could not be affected by local action. Opening businesses were required to follow specific guidelines that included checking employees for fever and respiratory symptoms, increasing sanitation in the workplace, wearing masks and gloves, social distancing, teleworking when possible, and staggering employee shifts.[65] On April 27, 2020, theaters, private social clubs, and dine-in restaurants were permitted to reopen, and on April 30, 2020, shelter-in-place orders expired for those not at high risk.[58]

On June 1, 2020, the maximum number of people allowed in gatherings where social distancing could not be maintained was increased from 10 to 25 and bars and night clubs were allowed to reopen as long as they limited capacity to 25 people or 35% of the total occupancy.[66] The same order permitted the resumption of professional and amateur sports teams. In another order on June 16, 2020 maximum size of gatherings increased from 25 to 50 (including in bars) and restaurants, dining rooms, and movie theaters no longer had a maximum party size or a limit on building capacity.[67]

Michigan began to reopen on May 1, 2020, when workers in industries that predominantly operate outside, such as construction, were allowed to return to work.[68] On May 18, 2020, restaurants and bars in the Traverse City and Upper Peninsula regions were allowed to open with limited capacity.[69] On May 21, 2020, an exception was added to the ongoing stay-at-home order to allow people to visit auto dealerships by appointment.[70] On June 1, 2020, Michigan's stay-at home-order was rescinded. Retailers opened on June 4, 2020, and restaurants, bars and swimming pools were allowed to open on June 8, 2020. Businesses with high amounts of contact with shared surfaces, such as gyms, hair salons, and theaters, stayed closed.[71]

### 3.5 Mask Mandates

On April 13, 2020 following CDC guidance, the Governor of Georgia issued an executive order making it legal for citizens to wear face masks for protection from the novel coronavirus.[72] In a series of five executive orders issued between April 23, 2020 and June 29, 2020, he continued to strongly encourage everyone to wear face masks in public except while eating, drinking, or exercising outside.[58,66,67,73,74]

On April 24, 2020, the Governor of Michigan issued an executive order that mandated all individuals to wear face coverings in public spaces who were medically able to do so, although no penalties were associated with non-compliance. Moreover, the order permitted businesses to refuse service to anyone not wearing a mask, and required businesses to provide masks to all employees who engage in in-person activities.[75]

### 3.6 Testing Centers

In Georgia, COVID-19 testing is free and available to all, regardless of symptoms. Testing is available at Georgia Department of Public Health (GDPH) locations upon scheduling an appointment or obtaining a referral. For each district, GDPH's website lists testing sites (48 statewide) within and counties it serves.[76] Free testing is also available at select CVS Health centers, local independent pharmacies, and Walgreens and Walmart locations.[77]

The Michigan Department of Health and Human Services (MDHHS) has more specific COVID-19 testing criteria, where COVID-19 test providers determine "if testing is appropriate based on symptoms and test availability in their area." Specifically, those that seek testing are ranked as "High Priority," "Priority," or "Permissible," based on qualities related to likelihood of infection and transmission. Asymptomatic individuals can fall into the "priority" and "permissible" categories if they meet certain criteria, such as working in a high-risk setting, and can therefore obtain testing.[78]

Michigan residents can obtain information on testing centers near a particular city or zip code by accessing a "Testing Site Finder Tool" on the Michigan.gov website. No-cost testing is also available at select CVS Health centers, and Kroger, Rite Aid, Walgreens, and Walmart locations.[77]

### 3.7 Policies for Recording Cases/Deaths

On April 5, the Council of State and Territorial Epidemiologists (CTSE) released a standardized surveillance case definition for COVID-19 to increase state transparency and promote consistency in case classification, quantification, and reporting.[79] This report detailed criteria to differentiate between confirmed cases, which require a positive molecular test, and probable cases, which may have a combination of clinical criteria, lab criteria, epidemiologic linkage, and COVID-19 cause of death reported on death certificates. The CTSE also recommended that states report both confirmed and probable cases of COVID-19. The CDC supported the proposal, recommending that all states utilize this classification and reporting system for COVID-19 cases,[80] but individual states were given discretion about inclusion of probable cases and probable deaths.

At the beginning of June, MDHHS started publicly reporting and differentiating between confirmed and probable cases, while Georgia has not clearly made such a distinction. Thus, the total case and death counts provided by the GDPH may not reflect all cases meeting "probable case" criteria. Underestimation of positive cases and deaths are possible when probable cases are not included. Additionally, Michigan may report COVID-19-related deaths faster than some states as a result of an emergency order requiring quicker notification and filing of COVID-19-related deaths with funeral directors and local registrars in order to make this data more immediately available to public health officials.[81] These factors are worthy of consideration and might play a role in Michigan's higher CFR, but there are likely other elements that more effectively explain the striking difference in CFR between these two states.

# 4 Disease Burden

## 4.1 Obesity

With obesity reaching epidemic proportions in the United States—where up to 42% of adults are classified as obese (body mass index [BMI] ≥ 30 $kg/m^2$) and 9% as severely obese (BMI ≥ 40 $kg/m^2$)—it is an important factor to consider in the context of COVID-19.[82,83] The CDC has identified that any degree of obesity is associated with poor prognosis in COVID-19 patients; severe obesity indicates even worse prognoses.[82,84]

The virus is known to enters cells via ACE2 receptors. These receptors are more highly expressed in adipose tissue than in the lungs.[82-84] Thus, obese people may have a higher viral load.[82-84] Additionally, adipocytes may significantly contribute to production of angiotensin II, which, by inducing pulmonary vasoconstriction, causes more severe lung injury (measured as $PaO_2$ to fraction of inspired oxygen) in COVID-19 patients.[82]

Common markers of obesity are chronically increased levels of circulating proinflammatory cytokines.[82-84] Hypertrophic adipocytes become more prone to activating endoplasmic reticulum and mitochondrial stress responses, leading to chronic inflammation that impairs macrophage activation and migration, decreases formation of antibodies and memory T cells, and suppresses activation of effector cells—all of which reduce immune function.[83] Obesity also increases airway resistance, reduces lung volumes, and causes respiratory muscle inefficiency.[82,83]

Considering the relationship obesity has with COVID-19, it is essential to recognize any potential differences that may exist between the two states:

**Table 4: Prevalence (95% CI) of Self-Reported Obesity by Race/Ethnicity, 2016-2018[85]**

| | Georgia | Michigan |
|---|---|---|
| **Non-Hispanic White Adults** | 30.1 (29.0 - 31.3) | 31.8 (31.0 - 32.5) |
| **Hispanic Adults** | 30.1 (26.6 - 33.9) | 36.9 (32.8 - 41.1) |
| **Non-Hispanic Black Adults** | 38.3 (36.5 - 40.1) | 39.9 (37.8 - 42.1) |

This data implies that differences may exist within races and ethnicities between the two states. In all groups, Michigan reported the same or higher rates of obesity. Furthermore, a self-administered survey from 2014 found the prevalence of overweight and obese to be 47.4 and 34.6% respectively for the whole sample, 39.9 and 43.6% for whites, and 42.3 and 47.8% for blacks in the Detroit metropolitan area.[86] Higher obesity rates throughout the state of Michigan could potentially contribute to its higher CFR.

## 4.2 Hypertension

Hypertension, defined as a systolic blood pressure ≥ 130 mm Hg or a diastolic blood pressure ≥ 80 mm Hg, is one of the most prevalent comorbidities in COVID-19 patients.[87-89] In one study by the CDC, nearly 53.5% of hospitalized COVID-19 patients reported having hypertension as an underlying medical condition.[90]

COVID-19 patients with hypertension have higher rates of mortality, acute respiratory distress syndrome (ARDS), need for ICU care, and disease progression. Hypertensive patients that regularly take medications such as ACE-inhibitors (ACEI) and angiotensin II receptor blockers (ARBs) have upregulated expression of ACE2, which could explain their greater propensity for infection.[91] While this connection may lead to the conclusion that ACEIs and ARBs should be discontinued in patients, research indicates that the effects of such medications are more beneficial than harmful, and as such should continue to be administered. Indeed, antihypertensives can actually help reduce systemic inflammation and reduce the likelihood of the development of ARDS, myocarditis, or acute kidney injury.[87,91]

A 2017 survey from the CDC indicates that 33.1% of Georgia adults had self-reported high blood pressure in comparison with 34.7% of Michigan adults. Table 5 below displays a breakdown of these individuals by Race[92]:

**Table 5: Prevalence (95% CI) of Self-Reported Hypertension by Race/Ethnicity, 2017**

| | Georgia | Michigan |
|---|---|---|
| **Non-Hispanic White Adults** | 35.2 (33.2-37.2) | 34.2 (33.0-35.4) |
| **Hispanic Adults** | 20.3 (16.7-24.4) | 23.9 (18.5-30.4) |
| **Non-Hispanic Black Adults** | 34.7 (31.9-37.6) | 44.2 (40.7-47.8) |
| **Non-Hispanic Asian** | 14.2 (8.2-23.4) | 13.6 (8.8-20.6) |
| **Other** | 32.1 (22.4-43.6) | 34.7 (25.5-45.2) |

While the overall prevalence of hypertension in Georgia and Michigan is comparable, disparities within races are clearer. Most notably, 9.5% more black adults in Michigan report high blood pressure. The interplay between the increased COVID-19 mortality rate in African Americans and in hypertensive individuals could contribute to the greater overall CFR in Michigan compared to Georgia.[93]

**4.3 Diabetes**

The Chinese Center for Disease Control and Prevention reported a higher mortality in COVID-19 patients with diabetes (7.3% diabetes vs. 2.3% overall) among 72,314 cases in the country.[83] Some reports like these from China and Italy have found increased mortality in diabetics, while other studies have not found any clear link.[94]

A key characteristic of diabetes is a low-grade chronic inflammation marked by increased oxidative stress (synthesis of superoxide) and production of advanced glycation end products (AGEs), pro-inflammatory cytokines, and inflammation modulatory adhesion molecules—all of which reduce immune function.[83,94] Also, elevated neutrophil-to-lymphocyte (NLR) and lymphocyte-to-C-reactive protein ratios in diabetics are found to be independent risk factors for cytokine storm. Alteration of the phenotype of neutrophils and natural killer (NK) cells—two cell types that provide host defense from COVID-19—is also a common feature across diabetics. This reduced immune function places diabetic patients at higher risk for severe COVID-19 outcomes.[83,94]

Besides the aforementioned immune effects, diabetics typically have reduced forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and diffusion capacity. These pulmonary changes, combined with the additional lung injury than can arise from oxidative stress, put diabetics at higher risk for severe COVID-19.[83,94]

Furthermore, the previously mentioned ACE2 receptors have been identified as an important link to COVID-19 infection. Expression of these receptors is known to increase after administration of traditional diabetes drugs such as thiazolidinediones, ACE inhibitors, ibuprofen, and ARBs. Hence, elevated ACE2 expression post-treatment could also increase risk of severe COVID-19 in diabetics.[94,95]

In 2016, Georgia (11.4%) had a higher prevalence of diabetes compared to Michigan (9.8%) in adults aged 20 years or older.[96] Given this anomaly, we examined the prevalence of diabetes in Atlanta and Detroit.

**Table 6: Number of diabetes cases in adults of 20 years or older in metropolitan areas of Atlanta and Detroit in 2016**[96]

| Metro Area | County | Diabetes Cases |
|---|---|---|
| **Atlanta** | Fulton | 62,274 |
| | Dekalb | 47,080 |
| | Gwinnett | 69,126 |
| | Cobb | 47,912 |
| | Clayton | 21,569 |
| | **Total** | **247,961** |
| **Detroit** | Wayne | 151,269 |
| | Macomb | 73,071 |
| | Oakland | 83,878 |
| | Washtenaw | 18,927 |
| | Livingston | 12,380 |
| | **Total** | **339,525** |

Data from each major metropolitan area (comprised of the city limits and its five major counties listed above) shows that Detroit has nearly 100,000 more diagnosed cases of diabetes than Atlanta. When adjusting for total populations in those counties, the Detroit metropolitan area had diabetic prevalence of 7.7%, while the Atlanta metropolitan area had prevalence of 6.7%—the opposite of the state trend. These data might contribute to Detroit's high CFR.

**4.4 Chronic Kidney Disease (CKD)**

According to the CDC, patients with any stage of CKD are "at an increased risk for severe illness from COVID-19," most likely because the direct and indirect effects of SARS-CoV-2 can lead to acute kidney injury (AKI). While patients without kidney disease might still experience coronavirus-mediated AKI, those with kidney disease at the time of hospital admission have higher rates of in-hospital death.[97]

Proximal convoluted tubule cells and podocytes have been shown to have "relatively high co-expression" of the *ACE2* and *TMPRSS* genes, and upon comparative analysis, these levels were no less than those of the lungs, esophagus, and intestines.[98] Past studies with MERS-CoV have identified the virus's direct cytotoxic effect on kidney cells due to receptor-induced apoptosis, and post-mortem studies of SARS-CoV have shown the presence of viral RNA in the kidneys; SARS-CoV-2 likely impacts the kidneys in a similar manner.[99,100]

The kidneys could also be susceptible to cytokine storm,[101] wherein the immune response increases vascular permeability, renal inflammation, and volume depletion. Some autopsies have supported this hypothesis by identifying erythrocyte aggregates in capillaries that lack platelets and other fibrinoid material.[102]

According to the National Kidney Foundation in Michigan, 1 in 7 adults in Michigan have CKD.[103] Although raw CKD data for Georgia was not publicly available, as of 2013, Georgia had 1,497 dialysis patients per million population, while Michigan had 1022 dialysis patients per million population.[104] In 2016, the prevalence of end-stage renal disease (ESRD) in Georgia and Michigan was 2,003 and 2,204 per million, respectively.[105]

One study of a Detroit patient population showed that CKD is independently associated with the need for ventilation/ICU care, after controlling for race and other major factors.[106] A study in six Atlanta hospitals and their associated outpatient clinics did not find an independent association of CKD with hospitalization.[107] Similarly, a study in southwest Georgia also did not find an independent association of CKD with in-hospital mortality.[108] These discrepancies between CKD and its impact on the severity of COVID-19 might have contributed to Michigan's higher CFR. However, there are likely confounding factors in the Detroit study.

### 4.5 Smoking/Select Chronic Respiratory Diseases

Factors associated with chronic lung diseases and smoking, like hypoxia, stress, and inflammatory mediators, may impact ACE2 expression.[109] When SARS-CoV-2 binds to an ACE2 receptor in a human airway epithelial cell, this action downregulates the receptor's ability to degrade angiotensin II into angiotensin I-VII.[110] Thus, the blocked action of ACE2 receptors reduces its anti-inflammatory and anti-fibrotic effects by indirectly causing a buildup of pro-inflammatory angiotensin II and worsening lung damage and inflammation after infection.[111,112] The role of ACE2 in SARS-CoV-2 infectivity combined with the protective effects of the enzyme creates a complex and contradictory relationship that highlights the importance of considering baseline ACE2 expression when predicting COVID-19 severity.[111]

Recent studies have suggested that chronic obstructive pulmonary disease (COPD) is a major risk factor for COVID-19.[113,114] Adults with COPD exhibit upregulated ACE2 and TMPRSS2 in lung airways; asthmatic adults show slight upregulation of these genes as well.[110] An association between COVID-19 and COPD exacerbation has been noted.[113] Additionally, due to innate immune dysfunction, one may expect asthmatics to have increased susceptibility for contracting viral infections,[115] but the link between asthma and contraction of COVID-19 is unclear. A study of patients from the UK BioBank found that asthma patients in the sample had significantly increased risk of severe symptoms after COVID-19 infection. The statistically significant association between non-allergic asthma and severe COVID-19 accounted for most of this effect.[116]

A systematic review found that smokers (who are more likely to have COPD[117]) with COVID-19 had increased rates of ICU admission, ventilation, and death.[118] Enhanced ACE2 expression and increased epithelial permeability have been hypothesized to facilitate viral entry in smokers.[117,119] Moreover, tobacco smoke causes increased oxidative stress, mucosal inflammation, and expression of inflammatory cytokines.[120] These cellular effects may contribute to the development of ARDS, the most common severe complication of COVID-19. Finally, smoking behavior—inhalation and hand-to-mouth movements—is thought to promote viral contamination.[121]

Michigan had a higher age-adjusted prevalence of COPD among adults over the age of 18 (7.8%) compared to Georgia (7.0%) in 2018.[122] The 2018 self-reported current asthma prevalence among adults was 8.9% in Georgia and 11.2% in Michigan.[123] The 2018 lifetime asthma prevalence among adults was 13.5% in Georgia and 16% in Michigan.[123] In both states in 2018, asthma disproportionately affected black non-Hispanics and multiracial non-Hispanics compared to white and other non-Hispanics.[123] Moreover, the 2018 self-reported prevalence of smoking among adults was 19.3% in Michigan and 17.5% in Georgia, with a greater percentage of non-Hispanic black individuals self-reporting tobacco use in Michigan (22.6%) versus Georgia (14%).[92] These differences may contribute to Michigan's higher CFR.

### 4.6 Cancer

Cancer patients are at a higher risk of contracting infections such as SARS-CoV-2. Some cancers can decrease the immune system's ability to fight infection while others damage the mucous membranes and barriers that protect our body compartments, making these compartments susceptible to pathogens. Furthermore, mucus secretions and drainage in the lungs could be impacted by a tumor, leading to infection. Cancer treatments ranging from surgery to chemotherapy might suppress or damage the immune system or increase a patient's nutritional requirements for maintaining immune system strength.[124,125] One study on 1,524 patients with cancer found that these patients had a twofold increased risk of SARS-CoV-2 infection compared to the general population.[126] Patients with lung cancer might have a higher risk of severe COVID-19 due to their already compromised lung function. In a Chinese study of a small cohort of COVID-19 patients, lung cancer was the most frequent type of cancer (28% of those with cancer).[127] Since lung cancer is the most common cancer in China, this result might not imply increased susceptibility.

The estimated annual incidences of cancer for 2020 in Georgia and Michigan are 55,190 and 61,770, respectively.[128,129] The annual cancer mortality in deaths per 100,000 population in Georgia and Michigan are 152.4 and 161.1, respectively.[130] These numbers might have played some role in Michigan's higher CFR.

### 4.7 Heart Disease

A statistically significant increase in COVID-19 mortality has been found for patients with coronary artery disease or history of heart failure or cardiac arrhythmia. Aside from viral infection of the heart via ACE2 receptors, dysfunction of vascular endothelial cells, stress cardiomyopathy, and decreased myocardial function due to inflammation may exacerbate pre-existing cardiac pathologies.[131] Cardiac injury, evidenced by elevated Troponin T (TnT), has been reported in 7-28% of COVID-19 patients.[132-134] While some COVID-19 patients without pre-existing cardiovascular disease (CVD) experienced cardiac injury contributing to a fatal outcome, the likelihood of cardiac injury and death was higher in patients with pre-existing CVD.[133]

The prevalence of heart disease (angina or coronary heart disease) in Georgia and Michigan are 4.6% and 5.0%, respectively.[135] The mortality due to heart disease in deaths per 100,000 population in Georgia and Michigan were 175.3 and 195.0, respectively.[136] This difference in mortality rates given similar prevalence may suggest that heart disease in Michigan is more severe and/or more poorly managed than in Georgia. This difference may contribute to Michigan's high CFR.

## 5 Vulnerable Populations

### 5.1 Advanced Age Populations and Assisted Living Communities

Elderly populations require increased attention when considering epidemiology, pathogenicity, and dangerous outcomes associated with COVID-19. An early retrospective and multi-center cohort study in Wuhan, China found that older age was associated with death in COVID-19 patients.[137] Provisional death counts based on death certificate coding show that a majority of COVID-19 deaths have occurred in patients 55 years of age and older, with an even higher mortality in patients 65 years of age and older.[138] Older adults often possess multiple comorbidities that may increase their susceptibility to COVID-19 infection with increased severity and necessity for intensive care.[139,140] With increasing age, the immune system typically becomes slower and less robust, which offers the opportunity for multisystem impact during infection. Age-related decrease in clearance of inhaled particles from small airways and fewer ciliated cells in large airways may also play a role in elderly susceptibility to COVID-19.[141] Furthermore, the elderly may experience changes in lung anatomy and muscle mass that can impair respiratory function and ultimately contribute to more serious clinical outcomes.[140] The presence of comorbid conditions introduces the aspects of polypharmacy and drug-drug interactions, and these topics warrant careful consideration as medical providers utilize various therapeutics while treating older patients with COVID-19.

Nursing homes and long-term care facilities pose challenges for COVID-19 infection control among older patients, too. Protecting nursing home and long-term care facility residents from novel coronavirus requires appropriate medical staff-to-patient ratios, adequate personal protective equipment, staff screening/contact tracing, and strict enforcement of limited visitor policies. Inadequacies in any of these areas can breech this patient population's safety against COVID-19. When combined with the risks for serious infection that are associated with older age, living situations in nursing homes and extended care facilities can be risky.

The Centers for Medicare and Medicaid Services (CMS) partnered with the CDC to compile updated information on COVID-19 cases and deaths in nursing homes around the United States. Using this dataset, it is possible to estimate the burden of COVID-19 on nursing homes in Georgia versus Michigan. The data were compiled on June 21, 2020 and summarized in the table below. While confirmed COVID-19 cases in nursing homes were similar between the two states, Michigan had over twice the nursing-home related deaths. It is currently unclear exactly why some nursing homes were impacted more than others. Michigan's struggle with ramping up COVID-19 testing earlier in the pandemic,[142] along with the state's stricter aforementioned criteria for access to testing, may have put this vulnerable group at increased risk of exposure.

**Table 7: CMS/CDC COVID-19 Nursing Home Data by State June 21, 2020**[143]

| State | Residents Total Confirmed COVID-19 | Residents Total COVID-19 Deaths | Staff Total Confirmed COVID-19 | Staff Total COVID-19 Deaths | Number of Nursing Homes Reporting |
|---|---|---|---|---|---|
| Georgia | 3,731 | 721 | 2,150 | 32 | 358 |
| Michigan | 3,575 | 1,726 | 3,056 | 26 | 440 |

## 5.2 African American Communities

As COVID-19 cases began to rise across the country, it became evident that minority populations, especially African Americans, were disproportionately affected by the global pandemic. The data reported as of June 30, 2020 shows that the African American population in Georgia had a confirmed case rate of 6,476.5 per million and a CFR of 381.36 per million, while the African American population in Michigan had a confirmed case rate of 13,045 per million and a CFR of 1,566 per million.[51,53] These numbers not only show that the black population in Michigan has twice Georgia's case rate, but also has a death rate approximately four times that of Georgia's black population.

Georgia has a higher percentage of black residents than Michigan—32.6% and 14.1%, respectively.[11] However, Detroit's African American population makes up 78.6% of its residents, Atlanta's 51.8%, and Albany's 73.5%.[32] Given the 43,565 cases in the Detroit MSA and 38,469 cases in the Atlanta MSA as of June 30, 2020, it is reasonable to assume that the Michigan's higher case rate in the African American population is partially attributable to this difference in the demographics of Detroit and Atlanta.

A recent study analyzing a five-hospital network in the Detroit metropolitan area found that race alone was not an independent risk factor for ventilation necessity or mortality due to COVID-19 complications. However, 72.1% of the patient base with COVID-19 was African American and 94% had at least one comorbidity.[106] This stands in contrast to an Atlanta study which found an independent association between black race and risk of hospitalization due to COVID-19.[107] Similar results were found in a study carried out in Louisiana between March 1, 2020 and April 11, 2020, in which black race was independently associated with increased risk of hospitalization but not in-hospital mortality.[144]

It is well-reported that African Americans are more likely to work in the service industry,[145] tend to have higher rates of comorbid conditions, and have a history of warranted distrust of the medical system. These inequities also affect the quality of care that minorities receive. As reported in the National Healthcare Quality & Disparities Report in 2018, Georgia was ranked in the 3rd quartile and Michigan in the 2nd quartile in regards to average differences in quality of care for Blacks, Hispanics, and Asians compared with Whites. In addition, nationally "12.3% of Black adults who had a doctor's office or clinic visit in the last 12 months and needed care, tests, or treatment sometimes or never found it easy to get the care, tests, or treatment compared with 6.8% of White adults."[47]

## 5.3 Children and Adolescents

Recent research has begun to unravel the susceptibility, transmission, and mortality parameters associated with COVID-19 in children, fortunately highlighting a reduced risk for contraction of the disease and overall mortality in children compared to adults.[146-148] However, long-term complications from COVID-19 are not yet fully understood, and the risk for significant impairment later in life should be explored further before allowing significantly increased social mobility of children.

In a retrospective analysis of 72,314 COVID-19 patients in China, only 2% of total cases fell into the age groups of <10 and 10-18 (416 cases and 549 cases, respectively).[147] Also interesting is the lack of mortality in children, where "no deaths occurred in the group aged 9 years and younger" in a study analyzing open-access genetics databases to evaluate mRNA expression levels of ACE2 and TMPRSS2 genes. Within the 4 child and 15 adult datasets analyzed, children demonstrated lower mRNA expression of both genes in bronchial and nasal epithelial tissues.[110] The authors hypothesize that this decreased expression of two cellular gateways for SARS-CoV-2 in upper and lower airway epithelial tissue could protect children from infection.

In another Chinese cohort, researchers found "young individuals (aged 0 to 14 years) had a lower risk of infection than individuals aged 15 and older.[146] This correlates well with data from Wuhan's Children's Hospital where suspected COVID-19 pediatric patients were assessed and treated: of 1,391 children assessed, 171 were found positive based on RNA testing (12.3%), 3 required "intensive care support and invasive mechanical ventilation" (0.22%), and one 10-month old child succumbed to the illness (0.07%).[148] This retrospective data shows a decreased COVID-19 rates and mortality in children compared to adults.

The ratios of infected children to adults in Georgia and Michigan are 1:13.4 and 1:19.9, respectively.[51,53] Thus, the aforementioned trend holds for children in Georgia and Michigan; adults continue to demonstrate higher susceptibility to infection than children. Although this is fortunate news for the sake of protecting the pediatric population, it has more complex implications for crafting healthcare guidelines and policies during an active pandemic. Schools, daycares, and other gatherings involving children could still see significant rates of transmission of SARS-CoV-2, and caution will be necessary to safely reinitiate children into regular activities without creating countless vectors for the virus to impact more vulnerable populations.

### 5.4 Incarcerated Populations

In the US, the prison population has been identified as an integral component of the national public health response to infectious agents and diseases. Close quarters, transient employees, limited healthcare and facilities, poor nutrition, high stress, and other characteristics of the American prison system seem to cultivate an environment where pathogens can easily spread and proliferate.[149-151] With an estimated prison population of 1,465,200 in 2018, the COVID-19 pandemic has forced the US to consider the health and economic consequences of inadequate health policy in local, state, and federal detention facilities in order to protect the incarcerated and the general public at large.[152]

Despite growing attention to public health policy affecting prisons, data from detention facilities in the US is impacted by insufficient reporting and is susceptible to manipulation by prison officials according to an analysis performed by the CDC in April 2020.[149] As a result, the US faces a unique and significant challenge in addressing public health concerns during the COVID-19 pandemic pertaining to its prison population. Also impacting the severity of the situation is the prevalence of comorbidities within US prison populations. Researchers at Harvard Medical School reported that "about half of the people incarcerated in [US] state prisons have at least 1 chronic [medical] condition," such as asthma, heart disease, and other medical conditions which have been observed to increase severity and mortality in COVID-19 cases.[151] This high prevalence of comorbidities has been hypothesized to contribute to the increasing case and death rates in prisons compared to general US populations. In a study performed by Johns Hopkins University School of Public Health researchers, it was reported "there had been

42,107 cases of COVID-19 and 510 deaths among 1,295,285 prisoners with a case rate of 3,251 per 100,000 prisoners," a rate that "was 5.5 times higher than the US population case rate of 587 per 100,000."[153] When accounting for age and sex distributions in the prison population, "the adjusted death rate… was 3.0 times higher than would be expected" than that of the general public. Based on this data, "prisoners are hospitalized and dying more frequently when infected."[153]

Despite a lack of universal reporting ("only 69% of [US prison] jurisdictions reported data" about test rates and positive test counts in prison facilities), Georgia and Michigan each have recognized the threat COVID-19 presents to incarcerated populations and begun to take action.[152] Utilizing data from 2018, a report on state prison demographics in the US found Georgia to have 53,647 prisoners; Michigan reported 38,761.[152] As a result, both states hold a significant number of citizens within detention facilities, potentially laying the foundation for recurring waves of COVID-19 infections from prison facilities to the community and back again.[151,152] Many suggestions have been generated to address this situation. For example, in DeKalb County, GA, a district judge ruled expedited release of 103 prisoners or 7% from the county jail, prioritizing release of non-violent or soon-to-be-released inmates in order to alleviate overcrowding and ease strain of the prison's healthcare system.[154] Other approaches to this problem include improvement of natural ventilation, increasing funding for mental health services to prisoners and staff amid the pandemic, monitoring of viral RNA levels in prison wastewater facilities to predict outbreaks, and similar early release actions.[150] These programs and initiatives would require significant funding, but they would also limit damages caused by COVID-19 within and outside of the incarcerated population. Given that Michigan and Georgia have each contained relative "hot spots" for COVID-19 cases, it would be proactive to begin mobilizing resources to healthcare efforts in jails and prisons in both states. Doing so would protect the surrounding communities and the detention facilities themselves from suffering rampant infections and subsequent high mortality rates, improve the health of the disproportionately affected minorities living in these detention facilities, and potentially save local and state health department resources for use in other areas.

### 5.5 Other Vulnerable Populations

There is little data available regarding the impact of COVID-19 on seasonal and migrant farmworkers. However, both Georgia and Michigan have reported outbreaks of COVID-19 in agricultural work settings.[155,156] One review of health issues among migrant and seasonal farmworkers compiled research that highlights the many health risks this population faces, including but not limited to infections, chemical/pesticide-related illnesses, dermatitis, respiratory conditions, and mental health disorders.[157] A multitude of factors contribute to the poor health outcomes of seasonal/migrant agricultural workers, including difficulty obtaining insurance due to documentation status, lack of knowledge regarding insurance eligibility criteria, difficulty establishing relationships with healthcare providers, language/cultural barriers, occupational health risks, low salaries, crowded housing conditions, and exposure to pesticides/toxins.[157] It is plausible that some of these factors may subject this population to increased risk for COVID-19 infections, and this uncertainty calls for special attention towards the health of migrant/seasonal farmworkers during the pandemic. However, this population is unlikely to have caused the discrepancy in CFR between Georgia and Michigan.

There is also little data available on the impact of COVID-19 on the rural populations of Georgia and Michigan. However, Georgia and Michigan have nearly identically sized rural populations, with 1,804,346 and 1,797,835 rural residents respectively.[158,159] Therefore, it is unlikely that differences in rural populations would be responsible for the difference in death rates between the two states.

## 6 Conclusion

The novel coronavirus SARS-CoV-2 and accompanying COVID-19 pandemic continues to have dire consequences in several regions across the world. By analyzing the mechanisms of infection, comorbidities, vulnerable populations, and other characteristics of the virus within the pandemic hotspots of Georgia and Michigan, we hope to enable communities to learn and adapt to the vulnerabilities which may expose them to increased infection and case fatality rates and understand which protective measures might improve outcomes.

In comparing Georgia and Michigan--two states with relatively high infection and case fatality rates within the US--we discovered important and actionable differences between the two regions. Michigan residents suffered a higher CFR in the general population, as well as within the pediatric, nursing home, and African American subgroups. Within Michigan, the city of Detroit also reported a higher age-adjusted mortality rate which may explain the higher overall COVID-19 infection rate in Michigan as compared with Georgia. We found that Michigan's relatively poor outcomes could be influenced by greater numbers of elderly (65+) and pediatric patients, a more vulnerable (but not larger) minority population, a lower income per capita, limited access to vital COVID-19 information via internet and television sources, and a lower proportion of residents holding at least a high school diploma.

The great number of factors contributing to a region's vulnerability to the SARS-CoV-2 coronavirus, as well as a significant list of emerging comorbidities, makes a single correlation difficult to identify. Furthermore, given the lack of complete data and the size (population-wide) of the data sets, we did not attempt a statistical analysis on any of the data we found. When available, statistical analyses found elsewhere in the literature were used to understand the links between some of the variables we examined and COVID-19 mortality in the US. Qualitative differences in data between the states and cities were noted where they occurred. This examination of data revealed a number of apparent correlations. Michigan's higher CFR may have been due to reduced capabilities of families and communities to social distance and obtain funds and information among other protective measures. Similarly, Michigan's minority populations appear to be at greater risk than Georgia's based on much higher confirmed case and death rates per million, suggesting greater risk for those with fewer resources in Michigan than in other high-risk areas. The results demonstrated a higher CFR in Michigan than in Georgia within elderly, pediatric, incarcerated, and other vulnerable populations. However, limitations on data reporting and standardization of results, such as omission of suspected cases in reported Georgia data but not Michigan data, may restrict the ability to make long-term, actionable conclusions.

## References


1. Yuki K, Fujiogi M, Koutsogiannaki S. COVID-19 pathophysiology: A review. Clin Immunol. 2020;215:108427. doi:10.1016/j.clim.2020.108427
2. Cascella M, Rajnik M, Cuomo A, Dulebohn SC, Di Napoli R. Features, Evaluation and Treatment Coronavirus (COVID-19). In: *StatPearls*. Treasure Island (FL): StatPearls Publishing; 2020.
3. Martines RB, Ritter JM, Matkovic E, et al. Pathology and pathogenesis of SARS-CoV-2 associated with fatal coronavirus disease, United States. [Published online ahead of print May 21, 2020]. *Emerg Infect Dis*. 2020;26(9):10.3201/eid2609.202095. doi:10.3201/eid2609.202095.
4. Common Human Coronaviruses. Centers for Disease Control and Prevention. https://www.cdc.gov/coronavirus/general-information.html. Published February 13, 2020. Accessed July 28, 2020.
5. Zou X, Chen K, Zou J, Han P, Hao J, Han Z. Single-cell RNA-seq data analysis on the receptor ACE2 expression reveals the potential risk of different human organs vulnerable to 2019-nCoV infection. *Front Med*. 2020;14(2):185-192. doi:10.1007/s11684-020-0754-0.
6. Qi F, Qian S, Zhang S, Zhang Z. Single cell RNA sequencing of 13 human tissues identify cell types and receptors of human coronaviruses. *Biochem Biophys Res Commun*. 2020;526(1):135-140. doi:10.1016/j.bbrc.2020.03.044.
7. Hoffmann M, Kleine-Weber H, Schroeder S, et al. SARS-CoV-2 cell entry depends on ACE2 and TMPRSS2 and is blocked by a clinically proven protease inhibitor. *Cell*. 2020;181(2):271-280.e8. doi:10.1016/j.cell.2020.02.052.
8. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet*. 2020;395(10223):497-506. doi:10.1016/S0140-6736(20)30183-5.
9. COVID-19 United States Cases by County. Johns Hopkins University. https://coronavirus.jhu.edu/us-map. Published June 30, 2020. Accessed July 29, 2020.
10. Executive Office of the President, Office of Management and Budget. OMB Bulletin 20-01, Revised Delineations of Metropolitan Statistical Areas, Micropolitan Statistical Areas, and Combined Statistical Areas, and Guidance on Uses of the Delineations of These Areas. https://www.whitehouse.gov/wp-content/uploads/2020/03/Bulletin-20-01.pdf?#. Published March 6, 2020. Accessed July 26, 2020.
11. QuickFacts: Michigan; Georgia. U.S. Census Bureau. https://www.census.gov/quickfacts/fact/table/MI,GA/PST045219. Accessed July 26, 2020.
12. U.S. Census Bureau. Metropolitan and Micropolitan Statistical Areas Population Totals and Components of Change: 2010-2019. https://www.census.gov/data/tables/time-series/demo/popest/2010s-total-metro-and-micro-statistical-areas.html. Published June 18, 2020. Accessed July 26, 2020.
13. U.S. Census Bureau. County Population Totals: 2010-2019. https://www.census.gov/data/tables/time-series/demo/popest/2010s-counties-total.html#par_textimage. Published June 22, 2020. Accessed July 28, 2020.
14. Newton J, Nepveux M. Feeding the Economy: Agricultural Jobs by State. American Farm Bureau Federation. https://www.fb.org/market-intel/feeding-the-economy-agricultural-jobs-by-state. Published March 21, 2019. Accessed July 22, 2020.
15. U.S. Department of Agriculture, National Agricultural Statistics Service. Quick Stats. https://quickstats.nass.usda.gov/results/ECF49B01-4293-3DBA-ABCD-AB9517B5B8B7. Accessed July 22, 2020.
16. Vaidya A. States ranked by hospital beds per 1,000 population. Becker's Hospital Review. https://www.beckershospitalreview.com/rankings-and-ratings/states-ranked-by-hospital-

beds-per-1-000-population.html. Published March 18, 2020. Accessed July 22, 2020.

17. American Nightlife Association. Market Summary: Nightlife Industry Overview. https://www.nightlifeassociation.org/market-overview/. Accessed July 22, 2020.
18. United Health Foundation, America's Health Rankings. Annual Report: Excessive Drinking in Michigan. https://www.americashealthrankings.org/explore/annual/measure/ExcessDrink/state/MI. Accessed July 22, 2020.
19. United Health Foundation, America's Health Rankings. Annual Report: Excessive Drinking in Georgia. https://www.americashealthrankings.org/explore/annual/measure/ExcessDrink/state/GA. Accessed July 22, 2020.
20. Wu X, Nethery RC, Sabath MB, Braun D, Dominici F. Exposure to air pollution and COVID-19 mortality in the United States: A nationwide cross-sectional study. [Published online ahead of print April 27, 2020]. *medRxiv*. 2020. doi:10.1101/2020.04.05.20054502.
21. Becker U, Deis A, Sørensen TI, et al. Prediction of risk of liver disease by alcohol intake, sex, and age: a prospective population study. *Hepatology*. 1996;23(5):1025-1029. doi:10.1002/hep.510230513.
22. Liver Disease Statistics. American Liver Foundation. https://liverfoundation.org/liver-disease-statistics/#alcohol-related-liver-disease-and-cirrhosis. Published October 26, 2017. Accessed July 22, 2020.
23. Center for Disease Control and Prevention, National Center for Health Statistics. Chronic Liver Disease/Cirrhosis Mortality by State. https://www.cdc.gov/nchs/pressroom/sosmap/liver_disease_mortality/liver_disease.htm. Accessed July 24, 2020.
24. Sun J, Aghemo A, Forner A, Valenti L. COVID-19 and liver disease. *Liver Int*. 2000;40(6):1278-1281. doi:10.1111/liv.14470.
25. Michigan Land area in square miles, 2010 by County. IndexMundi. https://www.indexmundi.com/facts/united-states/quick-facts/michigan/land-area#table. Accessed July 22, 2020.
26. U.S. Census Bureau. 2017 Gazeteer. https://www2.census.gov/geo/docs/maps-data/data/gazetteer/2017_Gazetteer/2017_gaz_place_26.txt. Accessed July 22, 2020.
27. U.S. Census Bureau. Metropolitan and Micropolitan Statistical Areas Population Totals and Components of Change: 2010-2019. https://www.census.gov/data/tables/time-series/demo/popest/2010s-total-metro-and-micro-statistical-areas.html. Published June 18, 2020. Accessed July 26, 2020.
28. Georgia Land area in square miles, 2010 by County. IndexMundi. https://www.indexmundi.com/facts/united-states/quick-facts/georgia/land-area#table. Accessed July 22, 2020.
29. U.S. Census Bureau. Annual Estimates of the Resident Population for Incorporated Places of 50,000 or More, Ranked by July 1, 2019 Population: April 1, 2010 to July 1, 2019. https://www2.census.gov/programs-surveys/popest/tables/2010-2019/cities/totals/SUB-IP-EST2019-ANNRNK.xlsx. Accessed July 22, 2020.
30. U.S. Census Bureau. 2018 Gazeteer. https://www2.census.gov/geo/docs/maps-data/data/gazetteer/2018_Gazetteer/2018_gaz_place_13.txt. Accessed July 22, 2020.
31. U.S. Department of Commerce, Bureau of Economic Analysis. Personal Income by County, Metro, and Other Areas: Metropolitan Area Table. https://www.bea.gov/data/income-saving/personal-income-county-metro-and-other-areas. Published November 14, 2019. Accessed July 22, 2020.
32. QuickFacts: Albany city, Georgia; Detroit city, Michigan; Atlanta city, Georgia. U.S. Census Bureau. https://www.census.gov/quickfacts/fact/table/albanycitygeorgia,detroitcitymichigan,atlantacitygeorgia/PST045219. Accessed July 22, 2020.
33. Race. U.S. Census Bureau. https://data.census.gov/cedsci/table?cid=P001001&tid=ACSDT1Y2018.B02001&hidePreview=true&t=Race%20and%20Ethnicity&vintage=2018&g=310M400US19820,12060_310M200US10500. Accessed July 22, 2020.

34. Educational Attainment. U.S. Census Bureau.https://data.census.gov/cedsci/table?g=310M400US12060,19820_310M200US10500&tid=ACSST1Y2018.S1501&t=Education%3AEducational%20Attainment&hidePreview=true&vintage=2018&layer=VT_2018_310_M4_PY_D1&cid=S1501_C01_001E. Accessed July 22, 2020.
35. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Environmental Information. Data Tools: 1981-2010 Normals. https://www.ncdc.noaa.gov/cdo-web/datatools/normals. Accessed July 22, 2020.
36. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Environmental Information. Average Relative Humidity - Morning (M), Afternoon (A). Accessed July 22, 2020.
37. Almanac: Historical Information. MyForecast. http://myforecast.co/bin/climate.m?city=13608&metric=true. Accessed July 22, 2020.
38. Tolbert C, Mossberger K. U.S. Current Population Survey & American Community Survey Geographic Estimates of Internet Use, 1997-2016. Arizona State University, Center on Technology, Data and Society. https://techdatasociety.asu.edu/broadband-data-portal/dataaccess/metrodata. Published 2018. Accessed July 22, 2020.
39. National Digital Inclusion Alliance. Worst Connected Cities 2018. https://www.digitalinclusion.org/worst-connected-2018/. Accessed July 22, 2020.
40. Federal Aviation Administration, Air Carrier Activity Information System. Commercial Service Airports (Rank Order) based on Calendar Year 2019 Preliminary. https://www.faa.gov/airports/planning_capacity/passenger_allcargo_stats/passenger/media/preliminary-cy19-commercial-service-enplanements.pdf. Published July 1, 2020. Accessed July 22, 2020.
41. Church Attendance Patterns by Zip Code. CityFlourish. https://cityflourish.com/church-attendance-patterns-by-zip-code/. Accessed July 26, 2020.
42. U.S. Environmental Protection Agency. Air Quality - Cities and Counties. https://www.epa.gov/air-trends/air-quality-cities-and-counties. Published May 5, 2020. Updated June 6, 2020. Accessed July 22, 2020.
43. Laden F, Schwartz J, Speizer FE, Dockery DW. Reduction in fine particulate air pollution and mortality. *Am J Respir Crit Care Med*. 2006;173(6):667-672. doi:10.1164/rccm.200503-443OC.
44. Pope CA III. Epidemiology of Fine Particulate Air Pollution and Human Health: Biologic Mechanisms and Who's at Risk? *Environ Health Perspect*. 200;108(Suppl 4):713-723. doi:10.1289/ehp.108-1637679.p
45. Wu Y, Jing W, Liu J, et al. Effects of temperature and humidity on the daily new cases and new deaths of COVID-19 in 166 countries. *Sci Total Environ*. 2020;729:139051. doi:10.1016/j.scitotenv.2020.139051.
46. Center for Disease Control and Prevention, Center for Disease Control and Prevention WONDER. Multiple Cause of Death File 2018, Series 20, No. 2X, 2020. https://wonder.cdc.gov/controller/datarequest/D76 Accessed July 20, 2020.
47. Agency for Healthcare Research and Quality. 2018 National Healthcare Quality and Disparities Report. https://www.ahrq.gov/sites/default/files/wysiwyg/research/findings/nhqrdr/2018qdr.pdf. Published September 2019. Accessed July 23, 2020.
48. Agency for Healthcare Research and Quality. National Healthcare Quality and Disparities Reports. https://nhqrnet.ahrq.gov/inhqrdr/Georgia/benchmark/summary/All_Measures/All_Topics. Accessed July 23, 2020.
49. Agency for Healthcare Research and Quality. National Healthcare Quality and Disparities Reports. https://nhqrnet.ahrq.gov/inhqrdr/Michigan/benchmark/summary/All_Measures/All_Topics. Accessed July 23, 2020.
50. U.S. Census Bureau. Health Insurance Coverage in the United States: 2018. https://www.census.gov/content/dam/Census/library/publications/2019/demo/p60-267.pdf.

Published November 2019. Accessed July 18, 2020.
51. Georgia Department of Public Health Daily Status Report. Georgia Department of Public Health website. Updated June 30, 2020, Accessed June 30, 2020. https://dph.georgia.gov/covid-19-daily-status-report
52. Office of Governor Brain P. Kemp. Officials Confirm Two Cases of COVID-19 in Georgia. https://gov.georgia.gov/press-releases/2020-03-03/gov-kemp-officials-confirm-two-cases-covid-19-georgia. Accessed July 18, 2020.
53. Michigan Data. Michigan Disease Surveillance System and Vital Records. Updated June 30, 2020, Accessed June 30, 2020. https://www.michigan.gov/coronavirus/0,9753,7-406-98163_98173---,00.html
54. State of Michigan. Michigan announces first presumptive positive cases of COVID-19. https://www.michigan.gov/coronavirus/0,9753,7-406-98158-521341--,00.html. Accessed July 27, 2020
55. Brian P. Kemp Office of the Governor. Executive Order 03.14.20.01. https://gov.georgia.gov/document/2020-executive-order/03142001/download Published March 14, 2020. Accessed July 24, 2020.
56. Brian P. Kemp Office of the Governor. Executive Order 03.23.20.01. https://gov.georgia.gov/document/2020-executive-order/03232001/download Published March 23, 2020. Accessed July 24, 2020.
57. Brian P. Kemp Office of the Governor. Executive Order 04.02.20.01. https://gov.georgia.gov/document/2020-executive-order/04022001/download Published April 2, 2020. Accessed July 24, 2020.
58. Governor Brian P. Kemp, Office of the Governor. Executive Order 04.23.20.02. https://gov.georgia.gov/document/2020-executive-order/04232002/download. Published April 23, 2020. Accessed July 22, 2020.
59. The Office of Governor Gretchen Whitmer. Executive Order 2020-04 (COVID-19). https://www.michigan.gov/whitmer/0,9309,7-387-90499_90705-521576--,00.html. Published March 10, 2020. Accessed July 24, 2020.
60. The Office of Governor Gretchen Whitmer. Executive Order 2020-05 (COVID-19). https://www.michigan.gov/whitmer/0,9309,7-387-90499_90705-521595--,00.html. Published March 13, 2020. Accessed July 24, 2020.
61. The Office of Governor Gretchen Whitmer. Executive Order 2020-11 (COVID-19). https://www.michigan.gov/whitmer/0,9309,7-387-90499_90705-521890--,00.html. Published March 16, 2020. Accessed July 24, 2020.
62. The Office of Governor Gretchen Whitmer. Executive Order 2020-17 (COVID-19). https://www.michigan.gov/whitmer/0,9309,7-387-90499_90705-522451--,00.html. Published March 21, 2020. Accessed July 24, 2020.
63. The Office of Governor Gretchen Whitmer. Executive Order 2020-21 (COVID-19). https://www.michigan.gov/whitmer/0,9309,7-387-90499_90705-522626--,00.html. Published March 24, 2020. Accessed July 24, 2020.
64. The Office of Governor Gretchen Whitmer. Executive Order 2020-42 (COVID-19). https://www.michigan.gov/whitmer/0,9309,7-387-90499_90705-525182--,00.html. Published April 9, 2020. Accessed July 24, 2020.
65. Governor Brian P. Kemp, Office of the Governor. Executive Order 04.20.20.01. https://gov.georgia.gov/document/2020-executive-order/04202001/download. Published April 20, 2020. Accessed July 20, 2020.
66. Governor Brian P. Kemp, Office of the Governor. Executive Order 05.28.20.02. https://gov.georgia.gov/document/2020-executive-order/05282002/download. Published May 28, 2020. Accessed July 22, 2020
67. Governor Brian P. Kemp, Office of the Governor. Executive Order 06.11.20.01. https://gov.georgia.gov/document/2020-executive-order/06112001/download.

Published June 11, 2020. Accessed July 22, 2020.
68. The Office of Governor Gretchen Whitmer. Executive Order 2020-70 (COVID-19). https://www.michigan.gov/whitmer/0,9309,7-387-90499_90705-527847--,00.html Published May 1, 2020. Accessed July 24, 2020.
69. The Office of Governor Gretchen Whitmer. Executive Order 2020-92 (COVID-19). https://www.michigan.gov/whitmer/0,9309,7-387-90499_90705-529476--,00.html Published May 18, 2020. Accessed July 24, 2020.
70. The Office of Governor Gretchen Whitmer. Executive Order 2020-96 (COVID-19). https://www.michigan.gov/whitmer/0,9309,7-387-90499_90705-529860--,00.html Published May 21, 2020. Accessed July 24, 2020.
71. The Office of Governor Gretchen Whitmer. Executive Order 2020-110 (COVID-19). https://www.michigan.gov/whitmer/0,9309,7-387-90499_90705-530620--,00.html Published June 1, 2020. Accessed July 24, 2020
72. Governor Brian P. Kemp, Office of the Governor. Executive Order 04.13.20.02. https://gov.georgia.gov/document/2020-executive-order/04132002/download. Published April 13, 2020. Accessed July 22, 2020.
73. Governor Brian P. Kemp, Office of the Governor. Executive Order 05.12.20.02. https://gov.georgia.gov/document/2020-executive-order/05122002/download. Published May 12, 2020. Accessed July 22, 2020.
74. Governor Brian P. Kemp, Office of the Governor. Executive Order 06.29.20.02. https://gov.georgia.gov/document/2020-executive-order/06292002/download. Published June 29, 2020. Accessed July 22, 2020.
75. The Office of Governor Gretchen Whitmer. Executive Order 2020-59 (COVID-19). https://www.michigan.gov/whitmer/0,9309,7-387-90499_90705-526894--,00.html/. Published April 24, 2020. Accessed July 20, 2020.
76. Georgia Department of Public Health. COVID-19 Testing in Georgia (2020). https://dph.georgia.gov/covidtesting. Accessed July 27, 2020.
77. U.S. Department of Health and Human Services. Community-Based Testing Sites for COVID-19. https://www.hhs.gov/coronavirus/community-based-testing-sites/index.html. Published July 24, 2020. Accessed July 27, 2020.
78. State of Michigan. MDHHS Expands COVID-19 Testing Criteria to Better Protect Residents; Greater access is important as Michigan reopens state economy. (2020). https://www.michigan.gov/coronavirus/0,9753,7-406-98163-530157--,00.html. Accessed July 27, 2020.
79. Coronavirus disease 2019 (COVID-19) 2020 interim case definition, approved April 5, 2020. Centers for Disease Control and Prevention - National Notifiable Diseases Surveillance System (NNDSS). https://wwwn.cdc.gov/nndss/conditions/coronavirus-disease-2019-covid-19/case-definition/2020/. Accessed July 24, 2020.
80. Council of State and Territorial Epidemiologists. Standardized Surveillance Case Definition and National Notification for 2019 Novel Coronavirus Disease (COVID-19). https://cste.us6.list-manage.com/track/click?u=a74794e707a0d58b86a809758&id=355d54d3a6&e=dfdc1f26f1. Published April 5, 2020. Accessed July 24, 2020.
81. Michigan Department of Health and Human Services. Emergency order under MCL 333.2253 – COVID-19 death reporting. https://www.michigan.gov/documents/coronavirus/MDHHS_epidemic_order_-_handling_of_bodily_remains_signed_689331_7.pdf. Published April 4, 2020. Accessed July 28, 2020.
82. Sanchis-Gomar F, Lavie CJ, Mehra MR, Henry BM, Lippi G. Obesity and outcomes in COVID-19: When an Epidemic and Pandemic Collide. *Mayo Clin Proc*. 2020;95(7):1445-1453. doi:10.1016/j.mayocp.2020.05.006.
83. Zhou Y, Chi J, Lv W, Wang Y. Obesity and diabetes as high-risk factors for severe coronavirus disease 2019 (Covid-19). [Published online ahead of print June 26,

2020]. *Diabetes Metab Res Rev*. 2020;e3377. doi:10.1002/dmrr.3377.

84. Dugail I, Amri EZ, Vitale N. High prevalence for obesity in severe COVID-19: Possible links and perspectives towards patient stratification. [Published online ahead of print July 8, 2020]. *Biochimie*. 2020;S0300-9084(20)30155-3. doi:10.1016/j.biochi.2020.07.001.
85. Centers for Disease Control and Prevention, Overweight and Obesity. Adult Obesity Maps. https://www.cdc.gov/obesity/data/prevalence-maps.html#age. Accessed July 22, 2020.
86. Jamil HJ, Rajan AK, Grzybowski M, Fakhouri M, Arnetz B. Obesity and overweight in ethnic minorities of the Detroit metropolitan area of Michigan. *J Community Health*. 2014;39(2):301-309. doi:10.1007/s10900-013-9760-3.
87. Schiffrin EL, Flack JM, Ito S, Muntner P, Webb RC. Hypertension and COVID-19. *Am J Hypertens*. 2020;33(5):373-374. doi:10.1093/ajh/hpaa057
88. Whelton PK, Carey RM, Aronow WS, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Hypertension*. 2018;71:e13–e115. DOI: 10.1161/HYP.0000000000000065.
89. Centers for Disease Control and Prevention (CDC). Hypertension Cascade: Hypertension Prevalence, Treatment and Control Estimates Among US Adults Aged 18 Years and Older Applying the Criteria From the American College of Cardiology and American Heart Association's 2017 Hypertension Guideline—NHANES 2013–2016. Atlanta, GA: US Department of Health and Human Services; 2019.
90. Centers for Disease Control and Prevention (CDC). COVIDView: A Weekly Surveillance Summary of U.S. COVID-19 Activity. https://www.cdc.gov/coronavirus/2019-ncov/covid data/covidview/index.html. Updated July 24, 2020. Accessed July 27, 2020.
91. Pranata R, Lim MA, Huang I, Raharjo SB, Lukito AA. Hypertension is associated with increased mortality and severity of disease in COVID-19 pneumonia: A systematic review, meta-analysis and meta-regression. *J Renin Angiotensin Aldosterone Syst*. 2020;21(2):1470320320926899. doi:10.1177/1470320320926899
92. Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Division for Heart Disease and Stroke Prevention. DHDSP Data Trends & Maps [online]. 2015. [accessed Jul 20, 2020]. URL: https://www.cdc.gov/dhdsp/maps/dtm/index.html.
93. Ferdinand K, Batieste T, Fleurestil M. Contemporary and Future Concepts on Hypertension in African Americans: COVID-19 and Beyond. *J Natl Med Assoc*. 2020;112(3):315-323. doi:10.1016/j.jnma.2020.05.018
94. Hussain A, Bhowmik B, do Vale Moreira NC. COVID-19 and diabetes: Knowledge in progress. *Diabetes Res Clin Pract*. 2020;162:108142. doi:10.1016/j.diabres.2020.108142.
95. Fang L, Karakiulakis G, Roth M. Are patients with hypertension and diabetes mellitus at increased risk for COVID-19 infection? [published correction appears in Lancet Respir Med. 2020 Jun;8(6):e54]. Lancet Respir Med. 2020;8(4):e21. doi:10.1016/S2213-2600(20)30116-8.
96. Centers for Disease Control and Prevention. Diagnosed Diabetes. cdc.gov. https://gis.cdc.gov/grasp/diabetes/DiabetesAtlas.html. Accessed July 24, 2020.
97. Cheng Y, Luo R, Wang K, et al. Kidney disease is associated with in-hospital death of patients with COVID-19. *Kidney Int*. 2020;97(5):829-838. doi:10.1016/j.kint.2020.03.005
98. Pan XW, Xu D, Zhang H, Zhou W, Wang LH, Cui XG. Identification of a potential mechanism of acute kidney injury during the COVID-19 outbreak: a study based on single-cell transcriptome analysis. *Intensive Care Med*. 2020;46(6):1114-1116. doi:10.1007/s00134-020-06026-1

99. Ding Y, He L, Zhang Q, et al. Organ distribution of severe acute respiratory syndrome (SARS) associated coronavirus (SARS-CoV) in SARS patients: implications for pathogenesis and virus transmission pathways. *J Pathol*. 2004;203(2):622-630. doi:10.1002/path.1560
100. Yeung ML, Yao Y, Jia L, et al. MERS coronavirus induces apoptosis in kidney and lung by upregulating Smad7 and FGF2. *Nat Microbiol*. 2016;1(3):16004. Published 2016 Feb 22. doi:10.1038/nmicrobiol.2016.4
101. Adapa S, Chenna A, Balla M, et al. COVID-19 Pandemic Causing Acute Kidney Injury and Impact on Patients With Chronic Kidney Disease and Renal Transplantation. *J Clin Med Res*. 2020;12(6):352-361. doi:10.14740/jocmr4200
102. Martinez-Rojas MA, Vega-Vega O, Bobadilla NA. Is the kidney a target of SARS-CoV-2?. *Am J Physiol Renal Physiol*. 2020;318(6):F1454-F1462. doi:10.1152/ajprenal.00160.2020
103. Kidney Disease. National Kidney Foundation of Michigan. https://www.nkfm.org/help-information/kidney-disease. Accessed July 24, 2020.
104. Kidney Disease-Is Your State Hard Hit? National Kidney Foundation. https://www.kidney.org/news/newsroom/nr/KD_StateHardHit. Published June 5, 2020. Accessed July 28, 2020.
105. Centers for Disease Control and Prevention. Chronic Kidney Disease Surveillance System—United States. http://www.cdc.gov/ckd. Accessed July 22, 2020.
106. Suleyman G, Fadel RA, Malette KM, et al. Clinical characteristics and morbidity associated with coronavirus disease 2019 in a series of patients in metropolitan detroit. *JAMA Netw Open*. 2020;3(6):e2012270. Published 2020 Jun 1. doi:10.1001/jamanetworkopen.2020.12270
107. Killerby ME, Link-Gelles R, Haight SC, et al. Characteristics Associated with Hospitalization Among Patients with COVID-19 - Metropolitan Atlanta, Georgia, March-April 2020. *MMWR Morb Mortal Wkly Rep*. 2020;69(25):790-794. Published 2020 Jun 26. doi:10.15585/mmwr.mm6925e1
108. Shah GH, Shankar P, Schwind JS, Sittaramane V. The Detrimental Impact of the COVID-19 Crisis on Health Equity and Social Determinants of Health. *J Public Health Manag Pract*. 2020;26(4):317-319. doi:10.1097/PHH.0000000000001200
109. Clarke NE, Belyaev ND, Lambert DW, Turner AJ. Epigenetic regulation of angiotensin-converting enzyme 2 (ACE2) by SIRT1 under conditions of cell energy stress. *Clin Sci (Lond)*. 2014;126(7):507-516. doi:10.1042/CS20130291.
110. Saheb Sharif-Askari NS, Saheb Sharif-Askari F, Alabed M, et al. Airways expression of SARS-CoV-2 receptor, ACE2, and TMPRSS2 is lower in children than adults and increases with smoking and COPD. *Mol Ther Methods Clin Dev*. 2020 May 22;(18):1-6. doi:10.1016/j.omtm.2020.05.013.
111. Verdecchia P, Cavallini C, Spanevello A, Angeli F. The pivotal link between ACE2 deficiency and SARS-CoV-2 infection. *Eur J Intern Med*. 2020;76:14-20. doi:10.1016/j.ejim.2020.04.037.
112. Rodrigues Prestes TR, Rocha NP, Miranda AS, Teixeira AL, Simoes-E-Silva AC. The anti-inflammatory potential of ACE2/angiotensin-(1-7)/Mas receptor axis: evidence from basic and clinical research. *Curr Drug Targets*. 2017;18(11):1301-1313. doi:10.2174/1389450117666160727142401.
113. Wang B, Li R, Lu Z, Huang Y. Does comorbidity increase the risk of patients with COVID-19: Evidence from meta-analysis. *Aging (Albany NY)*. 2020;12(7):6049-6057. doi:10.18632/aging.103000.
114. Nandy K, Salunke A, Pathak SK, et al. Coronavirus disease (COVID-19): A systematic review and meta-analysis to evaluate the impact of various comorbidities on serious events. [Published online ahead of print July 2, 2020]. *Diabetes Metab Syndr*. 2020;14(5):1017-1025.
115. Juhn YJ. Risks for infection in patients with asthma (or other atopic conditions): Is asthma more than a chronic airway disease?. *J Allergy Clin Immunol*. 2014;134(2):247-259. doi:10.1016/j.jaci.2014.04.024.

116. Zhu Z, Hasegawa K, Ma B, Fujiogi M, Camargo CA Jr, Liang L. Association of asthma and its genetic predisposition with the risk of severe COVID-19. [Published online ahead of print June 6, 2020]. *J Allergy Clin Immunol*. 2020;S0091-6749(20)30806-X. doi:10.1016/j.jaci.2020.06.001.
117. Brake SJ, Barnsley K, Lu W, McAlinden KD, et al. Smoking Upregulates Angiotensin-Converting Enzyme-2 Receptor: A Potential Adhesion Site for Novel Coronavirus SARS-CoV-2 (Covid-19). *J Clin Med*. 2020;9(3):841. Published 2020 Mar 20. doi:10.3390/jcm9030841
118. Vardavas CI, Nikitara K. COVID-19 and smoking: A systematic review of the evidence. *Tob Induc Dis*. 2020;18:20. Published 2020 Mar 20. doi:10.18332/tid/119324
119. Kaur, G., Lungarella, G., & Rahman, I. (2020). SARS-CoV-2 COVID-19 susceptibility and lung inflammatory storm by smoking and vaping. *Journal of inflammation (London, England)*, *17*, 21. https://doi.org/10.1186/s12950-020-00250-8
120. Strzelak, A., Ratajczak, A., Adamiec, A., & Feleszko, W. (2018). Tobacco Smoke Induces and Alters Immune Responses in the Lung Triggering Inflammation, Allergy, Asthma and Other Lung Diseases: A Mechanistic Review. *International journal of environmental research and public health*, *15*(5), 1033. https://doi.org/10.3390/ijerph15051033
121. Berlin, I., Thomas, D., Le Faou, A. L., & Cornuz, J. (2020). COVID-19 and smoking. *Nicotine & tobacco research : official journal of the Society for Research on Nicotine and Tobacco*, ntaa059. Advance online publication. https://doi.org/10.1093/ntr/ntaa059
122. Centers for Disease Control and Prevention, National Center for Chronic Disease and Prevention, Division of Population Health. Chronic Disease Indicators (CDI) Data, Category: Chronic Obstructive Pulmonary Disease. https://nccd.cdc.gov/cdi/rdPage.aspx?rdReport=DPH_CDI.ExploreByTopic&islTopic=COPD&islYear=9999&go=GO. Accessed July 24, 2020.
123. Centers for Disease Control and Prevention, National Center for Environmental Health. 2018 Adult Asthma Data: BRFSS Prevalence Tables and Maps. https://www.cdc.gov/asthma/brfss/2018/brfssdata.html. Updated March 26, 2020. Accessed July 24, 2020.
124. Gosain R, Abdou Y, Singh A, Rana N, Puzanov I, Ernstoff MS. COVID-19 and Cancer: a Comprehensive Review. *Curr Oncol Rep*. 2020;22(5):53. Published 2020 May 8. doi:10.1007/s11912-020-00934-7
125. Al-Shamsi HO, Alhazzani W, Alhuraiji A, et al. A Practical Approach to the Management of Cancer Patients During the Novel Coronavirus Disease 2019 (COVID-19) Pandemic: An International Collaborative Group. *Oncologist*. 2020;25(6):e936-e945. doi:10.1634/theoncologist.2020-0213
126. Yu J, Ouyang W, Chua MLK, Xie C. SARS-CoV-2 Transmission in Patients With Cancer at a Tertiary Care Hospital in Wuhan, China [published online ahead of print, 2020 Mar 25]. *JAMA Oncol*. 2020;6(7):1108-1110. doi:10.1001/jamaoncol.2020.0980
127. Liang W, Guan W, Chen R, et al. Cancer patients in SARS-CoV-2 infection: a nationwide analysis in China. *Lancet Oncol*. 2020;21(3):335-337. doi:10.1016/S1470-2045(20)30096-6
128. American Cancer Society, Cancer Statistics Center. Georgia. https://cancerstatisticscenter.cancer.org/#!/state/Georgia. Accessed July 22, 2020.
129. American Cancer Society, Cancer Statistics Center. Michigan. https://cancerstatisticscenter.cancer.org/#!/state/Michigan. Accessed July 22, 2020.
130. Centers for Disease Control and Prevention, National Center for Health Statistics. Cancer Mortality by State. https://www.cdc.gov/nchs/pressroom/sosmap

/cancer_mortality/cancer.htm. Updated April 29, 2020. Accessed July 22, 2020.

131. Mehra M, Desai SS, Kuy S, Henry TD, Patel AN. Cardiovascular disease, drug therapy, and mortality in Covid-19. *N Eng J Med*. 2020;382(e102):NEJMoa2007621. doi:10.1056/NEJMoa2007621.

132. Clerkin KJ, Fried JA, Raikhelkar J, et al. COVID-19 and cardiovascular disease. *Circulation*. 2020;141(20):1648-1655. doi: 10.1161/CIRCULATIONAHA.120.046941.

133. Guo T, Fan Y, Chen M, et al. Cardiovascular Implications of Fatal outcomes of patients with coronavirus disease 2019 (COVID-19). *JAMA Cardiol*. 2020;5(7):1-8. doi:10.1001/jamacardio.2020.1017.

134. Shi S, Qin M, Shen B, et al. Association of Cardiac Injury With Mortality in Hospitalized Patients With COVID-19 in Wuhan, China. *JAMA Cardiol*. 2020;5(7):802-810. doi:10.1001/jamacardio.2020.0950.

135. United Health Foundation, America's Health Rankings. Annual Report: Heart Disease in Georgia. https://www.americashealthrankings.org/explore/annual/measure/CHD/state/GA. Accessed July 22, 2020.

136. Centers for Disease Control and Prevention, National Center for Health Statistics. Heart Disease Mortality by State. https://www.cdc.gov/nchs/pressroom/sosmap/heart_disease_mortality/heart_disease.htm. Updated April 27, 2020. Accessed July 22, 2020.

137. Zhou F, Yu T, Du R, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *Lancet*. 2020;395(10229):1054-1062. doi:10.1016/S0140-6736(20)30566-3.

138. Centers for Disease Control and Prevention, National Center for Health Statistics. Provisional Deaths Counts for Coronavirus Disease (COVID-19). https://www.cdc.gov/nchs/nvss/vsrr/covid_weekly/index.htm#AgeAndSex. Updated July 22, 2020. Accessed July 24, 2020.

139. Wang D, Hu B, Hu C, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. [Published online ahead of print February 7, 2020]. *JAMA*. 2020;323(11):1061-1069. doi:10.1001/jama.2020.1585.

140. Liu K, Chen Y, Lin R, Han K. Clinical features of COVID-19 in elderly patients: a comparison with young and middle-aged patients. *J Infect*. 2020;80(6):e14-e18. doi:10.1016/j.jinf.2020.03.005.

141. Svartengren M, Falk R, Philipson K. Long-term clearance from small airways decreases with age. *Eur Respir J*. 2005;26(4):609-615. doi:10.1183/09031936.05.00002105.

142. Mack J. Michigan is ramping up coronavirus testing - that's easier said than done. MLive. https://www.mlive.com/public-interest/2020/04/michigan-is-ramping-up-coronavirus-testing-thats-easier-said-than-done.html. Published April 20, 2020. Accessed July 28, 2020.

143. Centers for Medicare and Medicaid Services. COVID-19 Nursing Home Data. https://data.cms.gov/stories/s/bkwz-xpvg Accessed July 15, 2020.

144. Price-Haywood EG, Burton J, Fort D, Seoane L. Hospitalization and Mortality among Black Patients and White Patients with Covid-19. *N Engl J Med*. 2020;382(26):2534-2543. doi:10.1056/NEJMsa2011686

145. U.S. Bureau of Labor Statistics. Labor force characteristics by race and ethnicity, 2018. https://www.bls.gov/opub/reports/race-and-ethnicity/2018/home.htm. Published October 2019. Accessed July 22, 2020.

146. Zhang J, Litvinova M, Liang Y, et al. Changes in contact patterns shape the dynamics of the COVID-19 outbreak in China. *Science*. 2020;368(6498):1481-1486. doi:10.1126/science.abb8001.

147. Wu Z, McGoogan JM. Characteristics of and important Lessons from the coronavirus

disease 2019 (COVID-19) outbreak in China: summary of a report of 72,314 cases from the Chinese Center for Disease Control and Prevention. *JAMA*. 2020;323(13):1239-1242. doi:10.1001/jama.2020.2648.

148. Lu X, Zhang L, Du H, et al. SARS-CoV-2 infection in children. *N Engl J Med*. 2020 April 23;382(17):1663-1665. doi:10.1056/NEJMc2005073.

149. Wallace M, Hagan L, Curran KG, et al. COVID-19 in correctional and detention facilities - United States, February-April 2020. *MMWR Morb Mortal Wkly Rep*. 2020 May 15;69(19):587-590. doi: 10.15585/mmwr.mm6919e1.

150. Wang J, Yang W, Pan L, et al. Prevention and control of COVID-19 in nursing homes, orphanages, and prisons. [Published online ahead of print on 2020 July 2] *Environ Pollut*. 2020;266(1):115161. doi: 10.1016/j.envpol.2020.115161.

151. Hawks L, Woolhandler S, McCormick D. COVID-19 in prisons and jails in the United States. [Published online ahead of print on 2020 April 28] . *JAMA Intern Med*. 2020. doi:10.1001/jamainternmed.2020.1856.

152. U.S. Department of Justice, Office of Justice Programs, Bureau of Justice Statistics. Prisoners in 2018. https://www.bjs.gov/content/pub/pdf/p18.pdf . Published 2020 April 30. Accessed 2020 July 22.

153. Saloner B, Parish K, Ward JA, et al. COVID-19 cases and deaths in federal and state prisons. [Published online ahead of print on 2020 July 8] *JAMA*. 2020;e2012528. doi: 10.1001/jama.2020.12528.

154. Boone C. DeKalb releases 103 inmates from jail; window dressing, critics say. Atlanta Journal Constitution. https://www.ajc.com/news/local/dekalb-releases-103-inmates-from-jail-window-dressing-critics-say/9Fkb485Fq3Fwq9XXD44peK/. Published 2020 April 14. Accessed 2020 July 22.

155. Erb R, Oosting J. Coronavirus outbreaks tied to migrant farm workers in Michigan. https://www.bridgemi.com/michigan-health-watch/coronavirus-outbreaks-tied-migrant-farm-workers-michigan. Published June 25, 2020. Accessed July 24, 2020.

156. Herbert C. Echols cases nearly triple after migrant worker testing. Valdosta Daily Times. https://www.valdostadailytimes.com/news/echols-cases-nearly-triple-after-migrant-worker-testing/article_d94166bc-9b67-11ea-a29a-a7e31eca372f.html. Published May 21, 2020. Accessed July 24, 2020.

157. Hansen E, Donohoe M. Health issues of migrant and seasonal farmworkers. *J Health Care Poor Underserved*. 2003;14(2):153-164. doi:10.1353/hpu.2010.0790.

158. United States Department of Agriculture Economic Research Service. State Fact Sheets: Georgia. USDA.gov. https://data.ers.usda.gov/reports.aspx?StateFIPS=13&StateName=Georgia&ID=17854 Updated May 13, 2020. Accessed July 24, 2020.

159. United States Department of Agriculture Economic Research Service. State Fact Sheets: Michigan. USDA.gov. https://data.ers.usda.gov/reports.aspx?StateFIPS=26&StateName=Michigan&ID=17854 Updated May 13, 2020. Accessed July 24, 2020.