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US-county level variation in intersecting individual, household and community characteristics relevant to COVID-19 and planning an equitable response: a cross-sectional analysis

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ABSTRACT

Objectives To illustrate the intersections of, and intercounty variation in, individual, household and community factors that influence the impact of COVID-19 on US counties and their ability to respond.

Design We identified key individual, household and community characteristics influencing COVID-19 risks of infection and survival, guided by international experiences and consideration of epidemiological parameters of importance. Using publicly available data, we developed an open-access online tool that allows county-specific querying and mapping of risk factors. As an illustrative example, we assess the pairwise intersections of age (individual level), poverty (household level) and prevalence of group homes (community-level) in US counties. We also examine how these factors intersect with the proportion of the population that is people of colour (ie, not non-Hispanic white), a metric that reflects histories of US race relations. We defined 'high' risk counties as those above the 75th percentile. This threshold can be changed using the online tool.

Setting US counties.

Participants Analyses are based on publicly available county-level data from the Area Health Resources Files, American Community Survey, Centers for Disease Control and Prevention Atlas file, National Center for Health Statistic and RWJF Community Health Rankings.

Results Our findings demonstrate significant intercounty variation in the distribution of individual, household and community characteristics that affect risks of infection, severe disease or mortality from COVID-19. About 9% of counties, affecting 10 million residents, are in higher risk categories for both age and group quarters. About 14% of counties, affecting 31 million residents, have both high levels of poverty and a high proportion of people of colour.

Conclusion Federal and state governments will benefit from recognising high intrastate, intercounty variation in population risks and response capacity. Equitable responses to the pandemic require strategies to protect those in counties at highest risk of adverse COVID-19 outcomes and their social and economic impacts.

Strengths and limitations of this study

► By demonstrating the high intercounty variation in a range of risk factors across US counties, including their intersection with communities of colour, this study highlights the need for policy-makers to consider their local context when addressing the COVID-19 pandemic.

► Approximately 9% of counties, affecting 10 million residents, are in higher risk categories for both age and group quarters, while approximately 14% of counties, affecting 31 million residents, have both high levels of poverty and a high proportion of people of colour.

► This study provides scientific guidance and an interactive data exploration tool to assist county-level and state-level policy-makers in planning an equitable response to COVID-19.

► While the list of variables examined is not exhaustive, an interactive online tool is made available for users to examine and compare 24 county-level characteristics.

► The study does not attempt to assign weights to these various risk factors, as it is not yet clear to how they will differentially impact risk of infection from COVID-19, and subsequent morbidity and mortality from it.

INTRODUCTION

The spread of COVID-19 across the USA confirms that not all Americans are equally at risk of infection, severe disease, or mortality. Researchers have noted significant disparities in the availability of critical medical resources that impact COVID-19 survival, such as ventilators, hospital beds and intensive care unit (ICU) beds.[1–4] However, a range of individual, household and community characteristics also influence risk of COVID-19 infection and its lethality. Preliminary data from the epidemic demonstrate a convergence of

these risk factors in communities with high proportions of low-income households, people of colour or both, differentially affecting counties across the USA.[5–7]

In this paper, we demonstrate wide intercounty variation in individual, household and community factors that influence risk of COVID-19 outcomes and provide an online tool for policy-makers to examine county-specific risk factors to plan an appropriate response (https://ccdd-hsph-harvard.shinyapps.io/county-risk/).

Current literature indicates that individual-level factors like age and pre-existing health conditions influence COVID-19 susceptibility and survival.[5 8 9] March 2020 data from a hospital-based surveillance system (COVID-NET) confirmed that 75% of all hospitalisations across 14 states in the USA were among those aged ≥50 years, with the highest hospitalisation rates among those aged ≥65.[5] Approximately 89% of COVID-19-associated hospitalised patients had one or more underlying conditions, including hypertension, obesity, chronic lung disease, diabetes and cardiovascular disease.[5]

Household characteristics such as household size, household composition (eg, grandparents living with grandchildren) and household crowding may affect contact patterns and transmission rates.[10] Moreover, poverty and job insecurity determine people's ability to work from home and 'shelter in place', at a time when non-pharmaceutical interventions are currently the primary defence against the outbreak.[11 12] Poverty heightens susceptibility to COVID-19 infection and risk of severe outcomes, due to its association with higher risk of comorbidities,[13] decreased access to care[13 14] and reduced ability to practice social distancing.[15 16] By April 2020, the Bronx, Philadelphia and Orleans Parish—counties with approximately one-fourth or more of its population below the poverty line—were among the counties with the highest cumulative death counts in the USA.[17] Community characteristics involving the presence of group quarters,[18] such as correctional facilities,[19 20] nursing homes[21–23] and homeless shelters,[24 25] are also implicated in COVID-19 risks. Local hospital-bed and ICU-bed capacity further determines a community's ability to respond to COVID-19.[3]

The intersection of these individual, household and community characteristics among communities of colour, created and perpetuated by the pervasive structural inequities in the USA, results in poor health outcomes.[26–28] Communities of colour are more likely to include low-income essential workers who cannot stay home, thereby increasing risk of exposure at work or on public transportation while commuting, as well as to live in more crowded housing.[29] In addition to increased risk of infection and mortality, communities of colour have increased risk of chronic diseases[30] and experience unequal access to healthcare,[6 31 32] further compounding risk of COVID-19 mortality. Populations of colour are also disproportionately unemployed[33] and incarcerated,[34] which independently increase the risk of COVID-19 infection and severe outcomes. These disparities, as manifestations of the effects of systemic racism

in the USA, contribute to higher COVID-19 death rates among predominantly black counties relative to predominantly white counties,[35] as well as to their higher age-specific risks of mortality among working-age adults.[36] Data from Detroit, New York City, New Orleans and Chicago—all cities with significant minority populations—reveal that African Americans comprise a disproportionate proportion of COVID-19 cases and deaths, relative to their share of the population.[31 35 37]

Understanding the distribution of these intersecting county-specific risk factors is critical to mounting an equitable, adequate, timely and comprehensive response. Inter-county differences are particularly important to consider in the context of supportive local policies around social distancing as the epidemic unfolds, and for the relaxation of social distancing in the coming months. Counties often have flexibility in determining the stringency of their COVID-19 response relative to their respective state orders[38 39]; therefore, counties represent a spatial and administrative unit ideal for localised response. Local response measures include both mobilisation of healthcare resources and optimisation of policies for social distancing and reopening. We provide an illustrative example of the convergence of individual, household and community factors, including their racial/ethnic composition, across all US counties to identify counties at heightened COVID-19 risk.

METHODS

Using publicly available county-specific data from the Area Health Resources Files,[40] American Community Survey,[41] Centers for Disease Control and Prevention Atlas file,[42] National Center for Health Statistics[43] and RWJF Community Health Rankings,[44] we identified a range of key individual, household and community factors influencing susceptibility to COVID-19, guided by international experiences and consideration of epidemiological parameters of importance. As an illustrative example, we examine the different pairwise intersections of age (an individual characteristic), poverty (a household characteristic) and prevalence of group homes (a community characteristic) in counties across the USA. We also examine how these factors intersect with the proportion of the population that is people of colour (ie, population other than non-Hispanic white), a metric that reflects histories of US race relations.

The accompanying open-access online tool (online supplementary materials text S1) is populated with each of these covariates and allows county-specific querying of different pairs of risk factors. In addition to displaying the county's rank relative to other counties, we display bivariate maps that illustrate the intersection of risk factors across the USA. All our data and code are publicly available to facilitate more nuanced analysis, inform existing models and shape policy (online supplementary materials text S1). For all covariates, we define low, medium and high risk as the below the 25th percentile, the 25–75th

RESULTS

Age and poverty

With respect to age, each county in the top quartile had at least 15% of their population over 70 years of age, compared with the median county of 12.8%. These older counties are clustered in the Midwest, Idaho, Florida and Nevada (online supplementary figure S1). For poverty, each county in the top quartile had at least 19% of their households under the poverty line, compared with the median county of 14.8%. These high poverty counties are clustered around Appalachia, Deep South states and along the USA–Mexico border (online supplementary figure S2). About 4% of US counties (135 of 3106), affecting over 2 million people, have both an older population and high rates of poverty (figure 1A). These counties are geographically dispersed, with little signs of clustering. The most impacted states are Florida (295 718 people in 7 of 67 counties), Arizona (198 858 people in 3 of 15 counties) and Arkansas (159 733 people in 14 of 75 counties).

Poverty and group quarters

For group quarters, each county in the top quartile had at least 4% of the resident population living in group quarters, compared with the median county of 1.9%. These counties are geographically dispersed across the entire USA (online supplementary figure S3). Nearly 4% of US counties (112 of 3111), affecting 2.2 million people, have both high poverty rates and are in the top quartile of proportion of the population living in group quarters (figure 1B). While these counties are clustered in Louisiana, Florida and New Mexico, the states with the most people affected are Pennsylvania (290 418 people in 6 of 67 counties), Florida (218 325 people in 6 of 67 counties) and New York (191 031 people in 4 of 62 counties).

Age and group quarters

Over 9% of US counties (285 of 3106), affecting over 10 million people, have both an older population and are in the top quartile of proportion of the population living in group quarters (figure 1C). These counties are geographically dispersed and show few signs of clustering. The most impacted states are Texas (1.4 million people in 40 of 254 counties), Georgia (1.2 million people in 20 of 67 counties) and Florida (711 168 people in 20 of 67 counties).

Intersections of individual, household and community characteristics in communities with a high proportion of people of colour

Regarding the composition of county populations, one quarter of counties in the USA (761) have at least 35% of their resident populations that are populations of colour (online supplementary figure S4). In 3% of US counties (89 of 3111), affecting 3.5 million people, the counties include both a high proportion of people of colour and a high proportion of older residents (figure 2A). In 14% of US counties (424 of 3106), affecting 31 million people, the counties include both a high proportion of people of colour and a high proportion of households living under the poverty line (figure 2B). In about 7% of US counties (229 of 3111), affecting 14 million people, the counties have both a high proportion of people of colour and are in the top quartile of proportion of people living in group quarters (figure 2C). Across the three risk factors, the intersection with counties with a high proportion of people of colour exhibits geographical variation. For example, clusters of counties with large populations of colour and older populations are found in Arizona, New Mexico and Colorado, but pockets also exist in Texas and Florida. This pattern is similar for counties with a high proportion of people of colour and proportion of people living in group quarters. By contrast, clusters of counties with a high proportion of people of colour and high poverty rates exist in the Deep South, in addition to Arizona, New Mexico and Texas.

DISCUSSION

Principal findings

Many Americans with chronic comorbidities, lack (and recent loss) of health insurance, inability to work from home and limited access to care are likely to be disproportionately affected by COVID-19, due to their increased risk of both infection and severe disease. Our findings demonstrate significant intercounty variation in the distribution of these risks, including their intersection with communities of colour.

Meaning of the study

Many of the counties that carry intersecting risks are located in states that have been tepid in their social-distancing response or in a haste to re-open.[6 45–47] In the absence of measures to enable social distancing and provision of adequate personal protective equipment to those that cannot stay home, communities of colour will likely continue to bear a disproportionately high burden of infection, severe disease and mortality.[6 31 35 37]

Areas with greater COVID-19 risk will likely have greater demand for hospital beds, and the ability of counties to mount a medical response to the outbreak will depend on local bed capacity. However, there is substantial geographical variation in hospital bed capacity. The median county has approximately 185 hospital beds per 100 000 population (mean: 294; IQR: 69–357; online supplementary figure S5). According to a May 2020 report from the US Society for Critical Care Medicine, only 1% (963) of all ICU beds are located in rural areas.[48] (See online supplementary figures S6–S9 for intersection of factors examined above and bed capacity.) In anticipation of heightened demands on healthcare systems during future waves of COVID-19 in counties that are multiply
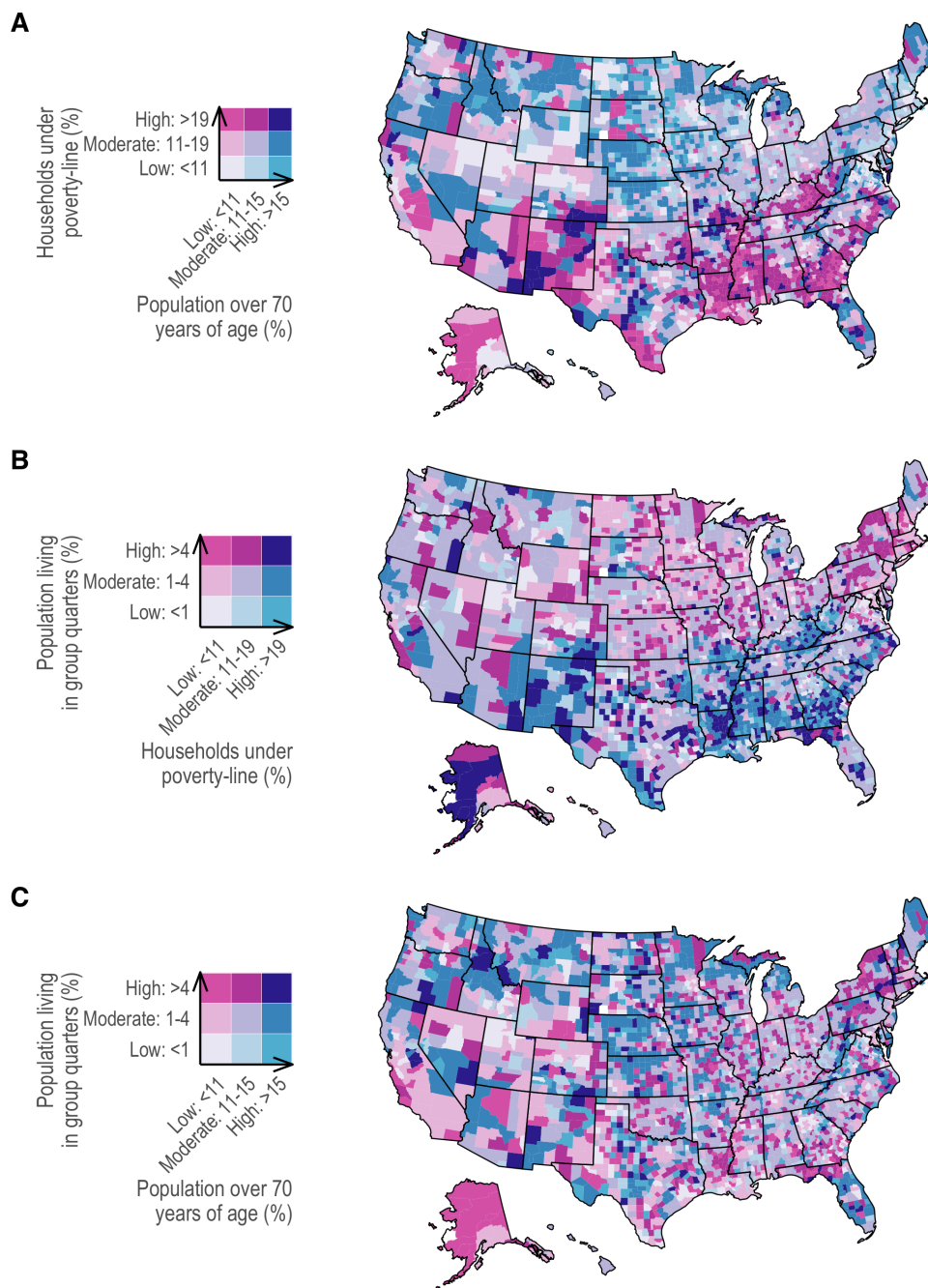
Patient and public involvement

Patients and the public were not involved in any way.

Figure 1 (A) Percentage of households living in poverty, 2016 (Source: CDC Atlas via the Census Small Area Income and Policy Estimates) and percentage of population 70 years or older, 2018 (Source: National Center for Health Statistics Bridged Race Population Estimates 2018, Vintage 2018). (B) Percentage of population living in group quarters, 2018 (Source: American Community Survey) and percentage of households living in poverty, 2016 (Source: CDC Atlas via the Census Small Area Income and Policy Estimates). (C) Percentage of population living in group quarters, 2018 (Source: American Community Survey) and percentage of population 70 years or older, 2018 (Source: National Center for Health Statistics Bridged Race Population Estimates 2018, Vintage 2018).

at risk of having high COVID-19 burden, states and the federal government need to ramp up interjurisdictional coordination efforts to move supplies and personnel to meet rapidly shifting local demands.

Limitations and future research

The risk factors described here are by no means a comprehensive list. Other important county-level characteristics are shown in online supplementary figures S10–S22 and can be found in the online dashboard. Additional risk factors on the county level that are not included in this analysis, such as the proportion of workers in industries that preclude working remotely, language, immigration status, numbers of incarcerated and homeless persons, measures of inequality like the Gini coefficient and Index of Concentration at the Extremes, and density of residential drug treatment programmes and residential mental health
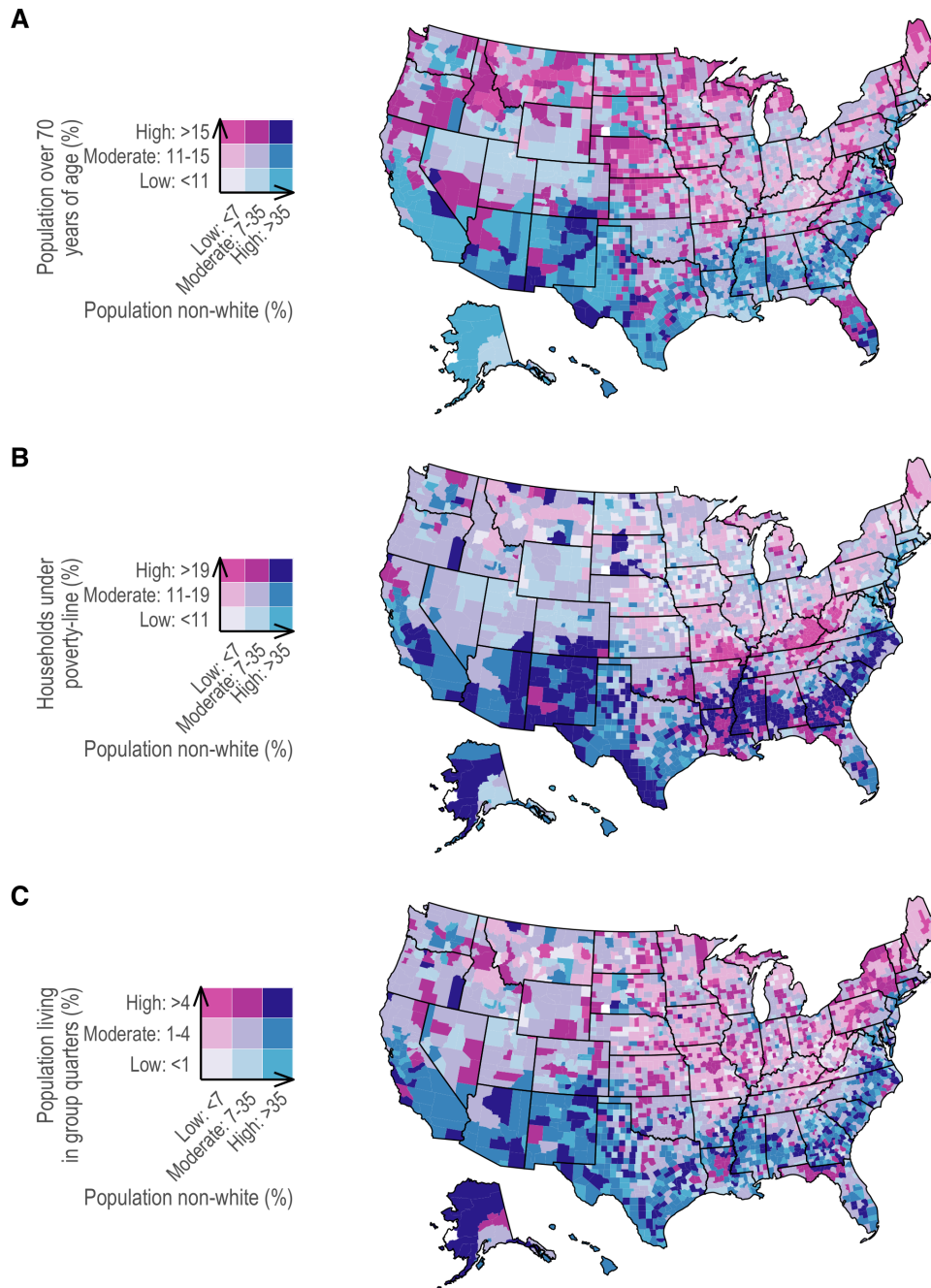
Figure 2 (A) Percentage of population 70 years or older, 2018 (Source: National Center for Health Statistics Bridged Race Population Estimates 2018, Vintage 2018) and percentage of population non-Hispanic and non-white, 2018 (Source: National Center for Health Statistics). (B) Percentage of households living in poverty, 2016 (Source: CDC Atlas via the Census Small Area Income and Policy Estimates) and percentage of population non-Hispanic and non-white, 2018 (Source: National Center for Health Statistics). (C) Percentage of population living in group quarters, 2018 (Source: American Community Survey) and percentage of population non-Hispanic and non-white, 2018 (Source: National Center for Health Statistics).

facilities, may all contribute to how counties are affected and respond. Currently, there is insufficient evidence to justify assigning importance weights to different risk factors; however, as more data become available, future research may expand on our analysis by, for example, constructing and evaluating a polysocial risk score.[49]

Conclusion

By July 6, there were more than 2.9 million cases in the USA, across all states, Washington D.C., and four US territories.[50] County, state and national planners will benefit from examining and preparing for the local factors that are likely to influence their counties' ability to respond. The need for actionable, contextually relevant data that allows for equitable distribution of resources to prevent, mitigate and treat COVID-19 is imperative. Collecting and sharing data on COVID-19 outcomes by race and ethnicity, which surveillance systems have not systematically reported for testing or hospitalisation (but

which are increasingly including these data for mortality), will be crucial to understanding and rectifying inequities in the distribution of COVID-19 outcomes.[17 51]

The clustering of counties with high concentrations of people of colour and high rates of poverty can be traced back to legacies of Jim Crow and race relations in the South.[27 28] In the absence of concerted, aggressive and proactive local responses, supported by state and federal agencies, the final morbidity and mortality toll, as early numbers indicate, will be disproportionately borne by these communities. Inaction will only perpetuate the structural inequities that are deeply entrenched in the USA.

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