Social inequality, chronic disease and COVID-19: county-level analysis in the United States

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Abstract

Background: Given the effect of chronic diseases on risk of severe COVID-19 infection, the present pandemic may have a particularly profound impact on socially disadvantaged counties.

Methods: Counties in the USA were categorised into five groups by level of social vulnerability, using the Social Vulnerability Index (a widely-used measure of social disadvantage) developed by the US Centers for Disease Control. The incidence and mortality from COVID-19, and the prevalence of major chronic conditions were calculated relative to the least vulnerable quintile using Poisson regression models.

Results: Among 3141 counties, there were 5,010,496 cases and 161,058 deaths from COVID-19 by August 10, 2020. Relative to the least vulnerable quintile, counties in the most vulnerable quintile had twice the rates of COVID-19 cases and deaths (rate ratios 2.11 [95%CI: 1.97-2.26] and 2.42 [2.22-2.64], respectively). Similarly, the prevalence of major chronic conditions was 24-40% higher in the most vulnerable counties. Geographic clustering of counties with high COVID-19 mortality, high chronic disease prevalence and high social vulnerability was found, especially in southern USA.

Conclusion: Some counties are experiencing a confluence of epidemics from COVID-19 and chronic diseases in the context of social disadvantage. Such counties are likely to require enhanced public health and social support.

Key words: COVID-19; Inequality; Vulnerability; Chronic disease; Syndemics

What is already known on this subject

In the past, pandemics have disproportionately affected poorer populations, widening existing social inequalities. Given the effect of chronic diseases on risk of severe COVID-19 infection, the present pandemic may have a particularly profound impact on socially disadvantaged counties. As the COVID-19 pandemic has now spread throughout the USA, there is growing evidence of disparities between different socio-economic groups in incidence and mortality from COVID-19. Yet the extent of these disparities, and how they might be addressed, requires further characterisation.

What this study adds

This national study of 3141 US counties used the Social Vulnerability Index (a widely-used measure of social disadvantage) to stratify counties, and found that as of August 10, 2020, the most socially disadvantaged counties had, on average, twice the rate of COVID-19 cases and deaths relative to the least disadvantaged counties. Similarly, the prevalence of major chronic conditions was also substantially higher in the most disadvantaged counties. Some counties are experiencing a confluence of epidemics from COVID-19 and chronic disease in the context of social disadvantage, which may exacerbate each other and further widen social inequalities. There was evidence of particular geographic clustering of such counties in the southern USA.

Introduction

In the past, pandemics have disproportionately affected poorer populations, widening existing social inequalities.[1–3] The coronavirus-2019 disease pandemic (COVID-19) has now spread throughout the USA, and there is growing evidence of disparities between different socio-economic groups in mortality from COVID-19.[4] Yet the extent of these disparities, and how they might be addressed, requires further characterisation.

Chronic conditions, including chronic obstructive pulmonary disease, heart disease, diabetes and chronic kidney disease, have emerged as important risk factors for severe illness from COVID-19 infection,[5] and there is a particular concern that socially disadvantaged populations might be affected by a confluence of epidemics from chronic diseases and COVID-19, which may exacerbate each other: a concept known as 'syndemics', defined as 'the presence of two or more disease states that adversely interact with each other, negatively affecting the mutual course of each disease trajectory, enhancing vulnerability, and which are made more deleterious by experienced inequities.'[6]

Social disadvantage has been variously measured. The US Centers for Disease Control and Prevention (CDC) has previously employed a Social Vulnerability Index (SVI; constructed using census data) to identify counties that are especially vulnerable to the economic and social consequences of a major environmental disaster.[7,8] However, empirical data on its value in identifying areas at particular risk during the current COVID-19 pandemic is scarce.

This study explores the social disparities in the effect of the COVID-19 pandemic between US counties. It aims to quantify the relation between county-level social disadvantage (as measured by SVI) and COVID-19 incidence and mortality. Such findings will inform our understanding of the social determinants of COVID-19, and the utility of measures such as SVI in the public health response to the pandemic. The study also aims to describe the geographic distribution of socially disadvantaged counties that have both high prevalence of chronic diseases and high mortality from COVID-19 (i.e., those counties that are experiencing a syndemic of diseases), which are likely to need particular public health and social support over the course of the pandemic.

Methods

County-level social vulnerability was assessed using the Social Vulnerability Index (SVI) developed by the US CDC, with data from the 2018 American Community Survey. Details of the parameters and methods used to construct the index have been described in detail elsewhere.[7,8] In brief, it is a composite measure of 15 socioeconomic and demographic factors reported in the US Census (including the level of poverty, unemployment, crowded housing, and health insurance coverage). The index was developed to identify counties that were most vulnerable to the social and economic impacts of major environmental disasters, and as such most likely to require public assistance after such an event; higher SVI score indicates greater social vulnerability.

County-level data on COVID-19 cases and deaths up to August 10, 2020 were obtained from USAFacts, a source of COVID-19 data used by the CDC (https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/previouscases.html). County-level prevalence of five major chronic conditions associated with COVID-19 severity among adults aged ≥18 years were obtained from US CDC, using data from the 2018 Behavioral Risk Factor Surveillance System (BRFSS) and the US Census population.[5] Information was obtained on the prevalence of obesity (BMI ≥30 kg/m^2), diabetes mellitus (type 1 and 2), chronic obstructive pulmonary disease, heart disease (angina or coronary heart disease, and myocardial infarction), and chronic kidney disease.[5]

Statistical analysis

We used Poisson regression, with the log of the population as an offset, to model the association between SVI and COVID-19 cases and deaths. We added a scale parameter to address the issue of potential overdispersion,[9] and used US States as a fixed-effect to adjust for State-level confounding factors.[10] We checked the robustness of these analyses by using negative binomial regression models. The same approach was used to examine the association between SVI and prevalence of the chronic conditions. We also mapped the joint distribution of COVID-19 mortality and each of the five chronic conditions in the most-deprived counties (4th and 5th quintiles combined). Statistical analysis was performed using Stata statistical software v. 14.2 (College Station, TX: StataCorp LLC) or Python (v. 3.7.7).

Results

After excluding one county due to missing information on SVI, 3141 counties from 50 states of the US and the District of Columbia were analysed, representing more than 327 million people. Relative to the lowest SVI quintile, counties in the highest quintile had a higher proportion of people in poverty (9.2% vs 23.6%), in unemployment (3.3% vs 8.7%), without health insurance (6.6% vs 14.3%), and from ethnic minority populations (9.7% vs 46.6%), but lower per capita income (USD 32K vs 21K) (online supplementary Table S1).

By August 10, 2020, a total of 5,010,496 cases and 161,058 deaths from COVID-19 had been reported. The rate of COVID-19 cases and deaths increased in a dose-response manner with increasing levels of SVI (Table). Compared with the lowest SVI quintile, the adjusted rates of COVID-19 cases in the 2nd, 3rd, 4th and 5th quintile were 24% (95% CI 16%-33%), 39% (30%-49%), 76% (65%-87%), and 111% (97%-126%) higher, respectively, while the rate of COVID-19 deaths was 19% (9%-30%), 22% (12%-33%), 77% (63%-92%), and 142% (122%-164%) higher, respectively. In sensitivity analyses, additionally adjusting for county-level proportions of people ≥65 years did not materially alter the findings. Neither was there any effect of restricting the analyses to counties with at least one COVID-19 case or death, or when using negative binomial regression models as opposed to Poisson regression models (online supplementary Table S2).

Higher levels of SVI was also associated with higher prevalence of each of the five chronic conditions (online supplementary Table S3). Compared with the lowest quintile, the adjusted prevalence of obesity, diabetes, chronic obstructive pulmonary disease, heath disease, and chronic kidney disease in the highest quintile was 24% (95% CI 22%-26%), 41% (39%-43%), 32% (28%-35%), and 25% (22%-28%), and 32% (30%-35%) higher, respectively.

Maps of the joint distribution of COVID-19 mortality with prevalence of each of the chronic conditions among the most deprived counties (4th and 5th SVI quintiles together) shows marked geographic clustering of areas with both high COVID-19 mortality and high prevalence of chronic disease (i.e., those counties experiencing a syndemic of diseases), particularly in the southern US states of Mississippi, Georgia, Louisiana, and Texas (Figure). However, there was substantial variation in both COVID mortality and chronic disease prevalence among counties, with many reporting low COVID mortality despite high

prevalence of chronic disease and social vulnerability. In analyses that compare the characteristics of counties with high levels of both COVID-19 mortality and chronic disease (i.e., counties experiencing a syndemic of diseases) to those counties with low levels of both COVID-19 mortality and chronic disease, the proportions of people ≥65 years did not differ between groups, whereas the proportion of people in poverty, unemployed, without health insurance or from an ethnic minority population was substantial higher among counties that experienced the syndemic (online supplementary Table S4).

Discussion

In this study of 3141 US counties, county-level SVI was strongly associated with both cases and deaths from COVID-19, with those in the highest SVI quintile having about double the rate of cases and deaths of those in the lowest quintile. SVI was also associated with the prevalence of each of the five major chronic conditions, and the mapping of counties indicated some areas (especially in the southern US) are experiencing a confluence of epidemics from chronic disease and COVID-19 in the context of social vulnerability.

Social disadvantage is strongly related to overcrowded living conditions, reduced likelihood of working conditions that permit physical distancing, and reduced likelihood of seeking and using healthcare services, among other factors that might exacerbate the impact of spread and clinical course of infectious disease epidemics.[11–14] Such populations are also more likely to suffer from chronic diseases, as found in the present report. Given chronic conditions, including heart disease, obesity and diabetes, are themselves major risk factors for the severity of COVID-19 infections, and it is becoming clear that the combined effects of social disadvantage itself on the potential for COVID-19 to propagate, together with the co-current chronic disease epidemic among these counties, is driving the disproportionate impact of COVID-19 on these populations.[15–17]

The social disruption accompanying the response to the COVID-19 pandemic has in turn adversely affected the management of chronic diseases, as well as the socioeconomic circumstances of the poorest counties, highlighting the complex syndemic nature of COVID-19. The mapping of counties in the present report illustrates that some areas are particularly

affected by chronic diseases, social disadvantage and the COVID-19 pandemic. However, there also some counties with high social vulnerability and high prevalence of chronic disease that have not experienced high rates of COVID-19 deaths, suggesting there may be important lessons from the response to the pandemic in these counties that could be applicable elsewhere.

It is also worth noting that some counties had lower prevalence of chronic conditions despite higher social vulnerability, including parts of Texas and California, which might be attributable to health and social policies in these states.[18,19] For example, California has been at the forefront of implementing a range of policy interventions to address smoking, such as an increased in cigarette tax. [18–20]

Our study has some limitations. First, the reporting of COVID-19 infections and deaths is dependant on testing, and the associations between SVI and rates of COVID-19 cases and deaths may be even stronger if testing is less prevalent in socially vulnerable areas. Second, the prevalence of chronic diseases examined in this study were obtained from Behavioral Risk Factor Surveillance System in 2018, which may be affected by non-response, and differential responses in the marginalized populations. Thirdly, these data do not distinguish the duration or severity of the chronic diseases examined. Lastly, although there were strong associations between social vulnerability and disease occurrence, it is not possible to exclude some residual confounding by other social or demographic factors (including age). Also, given the ecological fallacy, the findings should not be interpreted at an individual level.

This study highlights the importance of policy interventions to tackle the pandemic that more explicitly focus on health equity and social justice. A greater attention to, and proportionate resource mobilization for, disadvantaged counties is needed (including improved opportunities for COVID-19 testing and policies to support appropriate physical distancing), to ensure this pandemic does not widen existing social inequalities.

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Ethics approval: Since all the data were anonymous, aggregated without any personal information, and publicly available, ethics approval was deemed waived.

Patient and Public Involvement: Patient and public involvement was not applicable since this study did not involve patients and public directly. However, our findings will be appropriately disseminated to the public through personal and social communication tools.

Dissemination declaration: We will disseminate the main findings to the member of the public through personal and social media.

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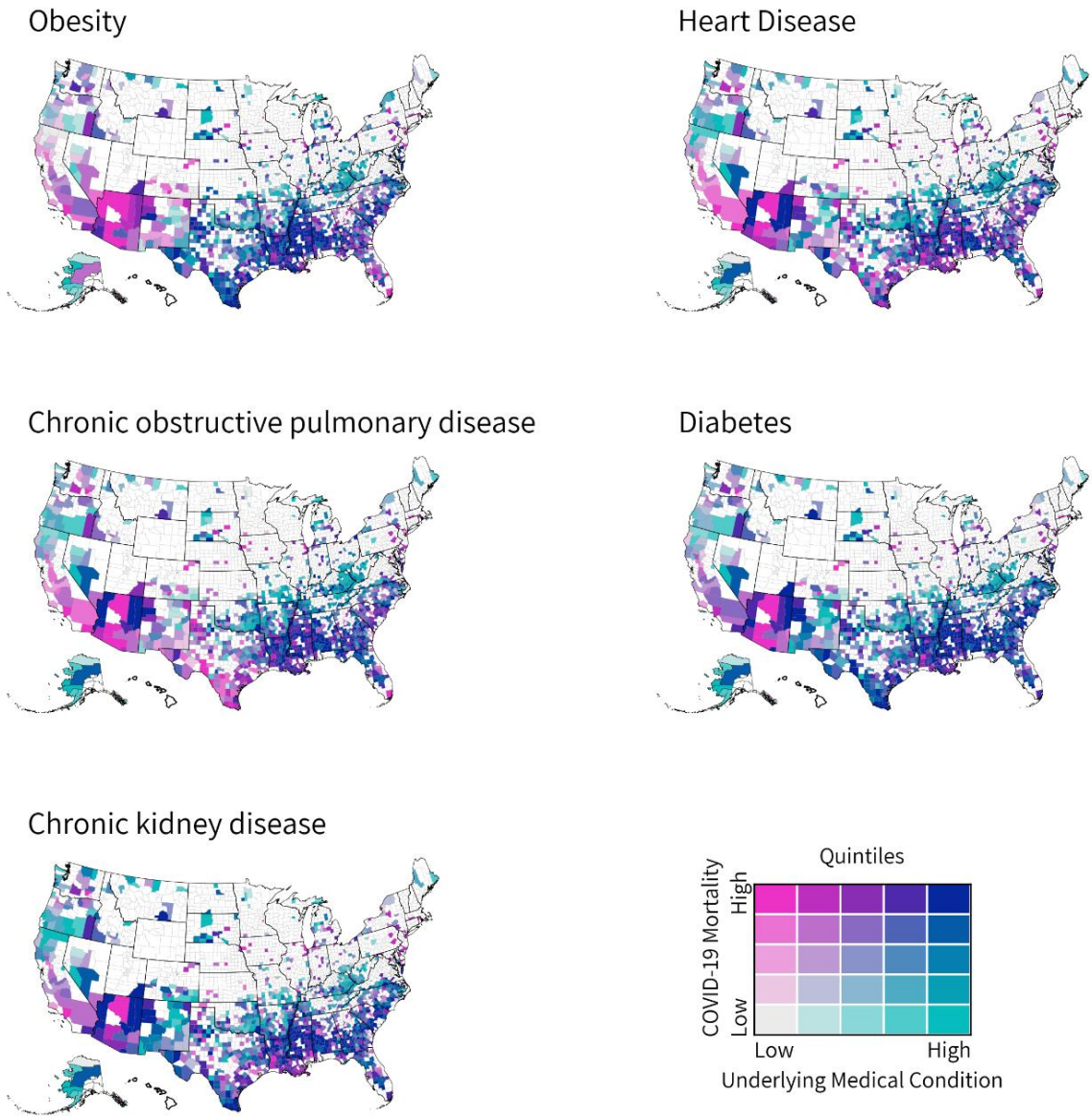
Table: COVID-19 cases and deaths in 3141 United States counties as of 10 August 2020, by quintiles of Social Vulnerability Index

	Social vulnerability index				
	1st quintile (least vulnerable)	2nd quintile	3rd quintile	4th quintile	5th quintile (most vulnerable)
COVID-19 cases					
Total cases	368,312	808,447	1,088,614	1,614,575	1,130,548
Crude rate per 100,000; median (IQR)	474 (279-786)	594 (331-1008)	670 (372-1272)	1009 (485-1849)	1816 (1020-2827)
Adjusted rate ratio (95% CI)	1.0 (*Ref.*)	1.24 (1.16-1.33)	1.39 (1.30-1.49)	1.76 (1.65-1.87)	2.11 (1.97-2.26)
COVID-19 deaths					
Total deaths	13,611	28,043	34,007	47,093	38,304
Crude rate per 100,000; median (IQR)	4 (0-15)	8 (0-23)	10 (0-27)	15 (4-41)	31 (12-68)
Adjusted rate ratio (95% CI)	1.0 (*Ref.*)	1.19 (1.09-1.30)	1.22 (1.12-1.33)	1.77 (1.63-1.92)	2.42 (2.22-2.64)

IQR=interquartile range. Rate ratios adjusted for US States as a fixed-effect (to adjust for State-level confounding factors) in the Poisson regression models using the log of the population as an offset term, and a scale parameter, set as the Pearson $\chi 2$ statistic divided by the residual degrees of freedom, to address the issue of potential overdispersion. Data: US Centres of Disease Control and Prevention (CDC) and USAFacts.

Figure: Geographic distribution of county-level prevalence of major chronic conditions and COVID-19 mortality rates as of 10 August 2020, among the most socially vulnerable counties in the United States



Analyses restricted to counties in the 4th and 5th quintiles of the Social Vulnerability Index of the US Centre of Disease Control and Prevention (US CDC). Maps give overlapping quintiles of county-level prevalence of major conditions (Table S3 in Supplementary material) with COVID-19 mortality rates (Table) up to 10 August 2020. Data: 2018 Behavioral Risk Factor Surveillance System; COVID-19 deaths from USAFacts.

Social inequality, chronic disease and COVID-19: county-level analysis in the United States

Supplementary Material

Table of Contents

Page

Table S1: Characteristics of 3141 US counties, by quintiles of Social Vulnerability Index

County-level characteristics	Social vulnerability index				
	1st quintile (least vulnerable)	2nd quintile	3rd quintile	4th quintile	5th quintile (most vulnerable)
Counties, n	629	628	628	628	628
Median (IQR) population (thousands)	16.9 (5.5-57.4)	31.2 (11.1-87.9)	31.0 (13.2-85.1)	29.9 (14.2-76.0)	23.7 (12.3-49.4)
Mean (SD) of % 65-years and above	20.6 (4.8)	19.9 (5.3)	19.4 (4.8)	18.7 (4.1)	17.7 (3.9)
Mean (SD) of % female	49.8 (1.2)	50.0 (1.6)	49.9 (2.3)	50.0 (2.5)	49.7 (3.2)
Mean (SD) of % in poverty	9.2 (2.8)	12.3 (3.1)	14.9 (3.7)	18.0 (4.0)	23.6 (6.3)
Mean (SD) of % unemployed	3.3 (1.5)	4.6 (1.6)	5.6 (1.8)	6.6 (2.3)	8.7 (3.4)
Mean (SD) of % uninsured	6.6 (3.0)	8.3 (3.8)	10.0 (4.7)	11.3 (4.4)	14.3 (5.6)
Mean (SD) of % ethnic minority	9.7 (7.8)	15.0 (11.9)	20.2 (15.6)	26.0 (18.2)	46.6 (21.0)
Median (IQR) per capita income (USD in thousands)	32.0 (28.9-35.1)	28.4 (26.3-31.3)	26.1 (23.9-28.9)	23.9 (21.8-26.3)	21.0 (18.8-23.2)

IQR= interquartile range. One county excluded from analyses due to missing social vulnerability index score. Social Vulnerability Index defined by the US Centers for Disease Control and Prevention (US CDC) with data from the 2018 American Community Survey.[15]

Table S2: Sensitivity analyses: association between Social Vulnerability Index and COVID-19 cases and deaths in 3141 United States counties as of 10 August 2020

	Social vulnerability index				
	1st quintile (least vulnerable)	2nd quintile	3rd quintile	4th quintile	5th quintile (most vulnerable)
COVID-19 cases					
Adjusted rate ratio (95% CI), using Poisson regression models* with additional adjustment for proportion of county population aged 65 years and older	1.0 (*Ref.*)	1.25 (1.17-1.33)	1.40 (1.31-1.49)	1.66 (1.56-1.76)	2.01 (1.88-2.14)
Adjusted rate ratio (95% CI), using Negative Binomial regression models	1.0 (*Ref.*)	1.24 (1.14-1.35)	1.46 (1.34-1.60)	1.79 (1.63-1.96)	2.60 (2.36-2.87)
COVID-19 deaths					
Adjusted rate ratio (95% CI), using Poisson regression models* with additional adjustment for proportion of county population aged 65 years and older	1.0 (*Ref.*)	1.19 (1.09-1.30)	1.20 (1.10-1.32)	1.67 (1.54-1.82)	2.26 (2.06-2.47)
Adjusted rate ratio (95% CI), using Negative Binomial regression models	1.0 (*Ref.*)	1.33 (1.14-1.53)	1.43 (1.23-1.67)	1.81 (1.55-2.12)	2.76 (2.33-3.25)

Data: US Centres of Disease Control and Prevention (CDC) and USAFacts.*Models were adjusted for US States as a fixed-effect to adjust for State-level confounding factors in the Poisson regression models using the log of the population as an offset term, and a scale parameter, set as the Pearson $\chi 2$ statistic divided by the residual degrees of freedom, to address the issue of potential overdispersion.

Table S3: County-level adult prevalence of major chronic conditions in 3141 US counties

	Social vulnerability index				
	1st quintile (least vulnerable)	2nd quintile	3rd quintile	4th quintile	5th quintile (most vulnerable)
Obesity					
Mean (SD) of county-level prevalence	32.6 (4.3)	33.5 (4.0)	34.4 (3.9)	36.2 (3.7)	38.5 (4.0)
Adjusted prevalence ratio	1.00 (*Ref.*)	1.03 (1.02-1.05)	1.08 (1.06-1.10)	1.15 (1.13-1.16)	1.24 (1.22-1.26)
Diabetes					
Mean (SD) of county-level prevalence	10.9 (1.6)	11.8 (2.0)	12.8 (2.1)	14.0 (2.1)	15.9 (2.5)
Adjusted prevalence ratio	1.00 (*Ref.*)	1.07 (1.05-1.09)	1.14 (1.12-1.16)	1.25 (1.23-1.27)	1.41 (1.39-1.43)
Chronic obstructive pulmonary disease					
Mean (SD) of county-level prevalence	7.4 (1.5)	8.4 (2.0)	9.2 (2.2)	10.1 (2.4)	10.3 (2.2)
Adjusted prevalence ratio	1.00 (*Ref.*)	1.07 (1.04-1.09)	1.14 (1.12-1.17)	1.20 (1.17-1.23)	1.32 (1.28-1.35)
Heart disease					
Mean (SD) of county-level prevalence	7.7 (1.4)	8.1 (1.7)	8.6 (1.7)	9.1 (1.7)	9.5 (1.6)
Adjusted prevalence ratio	1.00 (*Ref.*)	1.05 (1.02-1.07)	1.10 (1.08-1.13)	1.13 (1.10-1.15)	1.25 (1.22-1.28)
Chronic Kidney disease					
Mean (SD) of county-level prevalence	3.1 (0.4)	3.2 (0.5)	3.4 (0.5)	3.6 (0.5)	4.0 (0.5)
Adjusted prevalence ratio	1.00 (*Ref.*)	1.05 (1.04-1.07)	1.12 (1.10-1.13)	1.18 (1.17-1.20)	1.32 (1.30-1.35)

Prevalence estimates are among adults aged ≥18 years. Prevalence ratios adjusted for US States as a fixed-effect to adjust for State-level confounding factors in the Poisson regression models using the log of the population as an offset term, and a scale parameter, set as the Pearson $\chi 2$ statistic divided by the residual degrees of freedom, to address the issue of potential overdispersion. Data: US CDC, 2018 Behavioral Risk Factor Surveillance System (BRFSS) and the US Census population.

Table S4: Characteristics of US counties with and without the syndemic of chronic disease and severe COVID-19

County-level characteristics	Counties with the syndemic of chronic disease and severe COVID-19*	Counties without the syndemic of chronic disease and severe COVID-19†
Counties, n	603	566
Median (IQR) population (thousands)	22.9 (12.3-44.6)	18.8 (6.5-47.8)
Mean (SD) of % 65-years and above	18.8 (4.1)	19.8 (5.1)
Mean (SD) of % female	50.1 (2.8)	49.3 (2.2)
Mean (SD) of % in poverty	21.3 (6.7)	11.9 (4.7)
Mean (SD) of % unemployed	7.6 (3.1)	4.2 (2.2)
Mean (SD) of % uninsured	13.1 (5.3)	8.2 (4.2)
Mean (SD) of % ethnic minority	38.4 (22.6)	14.5 (13.2)
Median (IQR) per capita income (USD in thousands)	22.2 (19.9-24.5)	29.3 (26.2-32.6)

Data: US CDC, 2018 Behavioral Risk Factor Surveillance System (BRFSS), the US Census population, and USAFacts. *Counties with both high prevalence of any chronic disease (highest two quintiles for any chronic condition listed in table S3) and high COVID mortality (highest two quintiles for COVID mortality as in Table 1). †Counties with both low prevalence of any chronic disease (lowest two quintiles for any chronic condition listed in table S3) and low COVID mortality (lowest two quintiles for COVID mortality as in Table 1).