Analysis of Excess Mortality at the County Level in Alabama by Socioeconomic Factors

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ANALYSIS OF EXCESS MORTALITY AT THE COUNTY LEVEL IN ALABAMA BY SOCIOECONOMIC FACTORS

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ABSTRACT

Objective: Analyze county level socioeconomic factors and their association with Covid-19 excess mortality in Alabama.

Methods: Linear regression analyses were used to evaluate the association between potential risk factors assessed using the American Community survey (n = 40 counties and county clusters) and excess mortality in 2020 per 100,000 population. Excess mortality came from a previously published paper by Ackley et al.

Results: Median household income (per 1,000 dollars); an average county median household income that 1,000 dollars higher was associated with 6 per 100,000 lower excess mortality (β= -5.953 p-value <.0001, CL=-8.16 – (-3.75)), insurance status (percentage of county residents with insurance); a 1 percent greater proportion with health insurance per county was associated with a 21 per 100,000 greater excess mortality (β= -20.94 p-value=0.0090, CL=-36.35 – (-5.54)), unemployment rate percentage; a 1 percent greater unemployment rate per county was associated with a 15 per 100,000 greater excess mortality (β=15.07 p-value=0.0169, CL=2.86 – 27.27), median age in years; an average county age that was one year higher was associated with 13 per 100,000 greater excess (β=13.61 p-value=0.0045, CL=4.50 – 22.77), the percentage of those who identify as Asian; a 1 percent greater proportion of county identified as Asian was associated with 50 per 100,000 lower excess mortality controlling for all other races/ethnicities included (β= -50.49 p-value = 0.0027, CL=-82.24 – (-18.74)) were significantly associated with excess mortality. In the multivariable-adjusted regression, only median household income (β= -4.49 p-value =0.0483, CL=-8.95 – (-0.036)) was statistically significant. An average county median household income that 1,000 dollars higher was associated with 4 per 100,000 lower excess mortality, controlling for median age, unemployment rate, insurance status, and race/ethnicity.

Conclusions: Income level was the socioeconomic factor that was associated with Covid-19 excess mortality. Additional research is needed to fully understand the extent to which and why median household income is associated with Covid-19 mortality.

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INTRODUCTION

Excess mortality can be used to measure the severity of Covid-19 disease within a population as well as the indirect effects of the pandemic, such as deaths that are not directly attributed to the SARS_CoV-2 infection.[1] Excess mortality is defined as the amount of death over what is expected (predicted) based on the mortality trends in the population.[2] Excess mortality compensates for variation in how the cause of death is coded and access to testing and can be standardized to make it comparable across different populations. Excess mortality includes both direct Covid-19 deaths and deaths indirectly associated with the pandemic, for example, because of lack of adequate health care for other conditions.[3] The factors driving excess mortality during the Covid-19 pandemic are not fully elucidated. However, there are geographic differences in excess mortality in the United States, with Alabama having one of the highest excess mortality rates in 2020 219.0 per 100,000.[4]

Chronic diseases that weaken the immune system, such as cancer and diabetes, put people at an increased risk of death from Covid-19 disease.[5]. Albitar et al. found that older age, male sex, hypertension, and diabetes mellitus were all associated with higher odds of dying from Covid-19 disease among patients hospitalized for Covid-19 disease. However, the higher adjusted odds of mortality for men compared to women were attributed to men having a higher prevalence of chronic comorbidities.[6] Comorbid conditions can vary geographically; according to Behavioral Risk Factor Surveillance System (BRFSS) in 2015 the prevalence of obesity ranged across states from 19.9% to 36.0% and diabetes in adults aged 45 and older ranged 11.2% to 26.8%.[7] This same concept can be applied to access to and the quality of care received. As quality of access to health care varies geographically it can increase or decrease a person's overall health and health outcomes of chronic conditions or infectious diseases.

Social disparities can create health disparities as people may live in environments that increase their risk of developing these comorbid conditions. Health disparities can also result from differences in the access to and quality of healthcare received across race, ethnic or socioeconomic groups.[8] Those with access to better healthcare tend to have better outcomes such as lower disease prevalence and lower mortality rate.[8] Systematic disparities vary across different areas of the country, states, and counties.[9] An example of this is that rural counties tend to have lower age of death and a higher prevalence of preventable conditions, while urban counties tend to have food deserts, higher rates of violence, and air pollution.[9]

Social determinates of health include income, social inclusion and non-discrimination, education, food security, and access to affordable health services of decent quality, as reported by the World Health Organization. [10] As stated in Healthy People 2030, 1 in 10 people in the US live in poverty and cannot afford healthy foods, health care, and housing. Healthy People also states that people with higher education levels are more likely to be healthy and live longer.[11] A simulation study completed using NHANES data by Seligman et al. found that US mortality from Covid-19 infection inordinately affects people from low- or middle-income families and people with less education.[12] Many of these social determinants of health are related to the areas in which individuals live. Rajub Paul et al. found that unemployment rates were associated with Covid-19 disease mortality rates in urban counties and that rural counties with a higher percentage of some college and associate degrees had substantially lower mortality rates from Covid-19 disease.[13]

The objective of this study was to examine whether county-level socioeconomic factors were associated with excess mortality during the first year of the Covid-19 pandemic. We specifically examined Alabama because it ranked 49th in Life Expectancy at Birth in 2016 meaning that people in Alabama are not living as long as people in other states and because it had one of the highest excess mortality rates during 2020 of 219.0 per 100,000.[14] [4]

METHODS

We conducted an ecological study in which Alabama counties or groups of counties were the units of observation. Excess mortality was the outcome of choice because it provides a broader picture of how much effect Covid-19 had while being less affected by access to and reliability of Covid-19 testing and death certificate coding than Covid-19 specific mortality. This study examined whether, county-level socioeconomic factors were associated with excess mortality. The University of Alabama at Birmingham Institutional Review Board approved this research as part of a larger project on Covid-19 testing.

We obtained excess mortality data from a previously published study. In the study, excess mortality was calculated by first creating a prediction/trend analysis for what 2020 mortality would be in the absence of Covid-19, using historical data from the years 2011-2019, retrieved from the CDC Wonder, using a quasi-Poisson generalized linear model.[15] Observed county-level mortality data came from National Center for Health Statistics and excess mortality was defined as the difference between predicted mortality and observed mortality.[15] Counties with a population of 50,000 or more stood alone (N=24), and smaller groups of counties were combined to form sets with a total population exceeding 50,000 (N=16). [15] Counties in Alabama that were clustered into 16 clusters, include Barbour-Bullock-Henry, Bibb-Chilton-Coosa-Perry, Butler-Crenshaw-Pike, Chambers-Cleburne-Randolph, Cherokee-Etowah, Choctaw-Clarke-

Washington, Clay-Tallagega, Coffee-Geneva, Conecuh-Marengo-Monroe-Wilcox, Covington-Escambia, Dallas-Lowndes, Fayette-Lamar-Marion, Franklin-Lawrence, Greene-Hale-Pickens-Sumter, Macon-Tallapoosa, and Walker-Winston. We also converted the excess mortality numbers into a rate per 100,000 which is the outcome variable that was chosen for this analysis.

Exposure variables included county-level distribution of race and ethnicity, rurality, age, income level, insurance status, unemployment rates, and education level. Data were obtained from the publicly available American Community Survey 2019 5-year estimates. The American Community Survey is a publicly available ongoing survey by the US Census Bureau that provides information and statistics about the US population.[16] For those counties that were clustered for the estimate of excess mortality, the variables were averaged together except for total population which was summed. For rurality, variable total population estimates were used and recoded to Metro vs. Micro using the HRSA definition. The HRSA definition of Metro is urban core of 50,000 or more people and Micro areas is urban core of 10,000-49,9999 people. For example, a county cluster that consist of a metro county and a micro county would be considered a metro cluster as the total population size of both counties is greater than 50,000. Variables are summarized in Table 1.

We used Pearson correlations to examine relationships between the county-level socioeconomic characteristics. We modeled the association of county-level socioeconomic characteristics with 2020 excess mortality per 100,000 using linear regression. First, all exposure variables were modeled individually, and then statistically significant variables were included together in a multivariable-adjusted analysis. For education level and race, we included all but one of the categories in the regression model. For example, we omitted White race, which provided the interpretation of the beta coefficients for African American race as the expected difference in excess mortality for a 1 percentage point greater African American population and 1 percentage point lower White population, holding other race/ethnic groups constant. Then, secondary analysis for effect modification where run on all variables in the multivariable-adjusted regression by including interaction terms in the models. SAS 9.4 was used to conduct all statical analyses, and p-values < 0.05 were considered statistically significant.

RESULTS

As seen in Table 2, the sample of counties and county clusters consisted of an average total population of around 119,000 people (119,126 ± 119,832) and an average age of 40 years (40.12 ± 2.75 years). Most counties consisted of primarily White individuals and African Americans individuals (68.32% ± 17.09% and 24.18% ± 18.65%, respectively), and the education level reached was most commonly high school graduate and some college (33.80% ± 5.59% and 21.10% ± 1.98% respectively). Most counties were considered Metro (n=37, 92.50%) versus Micro (n=3, 7.50%), and average unemployment rate was 6.3% (6.26% ± 2.13%). The median household income was $47,000 ($47,049 ± $9501), and approximately 90% of the residents of every county had health insurance (90.19% ± 1.66%). The average number of expected deaths per county in 2020 was 1391 (1391.03 ± 1263.35), the average number of observed deaths was 1619 (1619.40 ± 1424.34), and the average number of excess deaths was 217 per 100,000 (216.98 ± 85.30 per 100,000).

Table 3 displays the correlation between the county-level socioeconomic factors. Some of the significant correlations are between median age and median household income (-0.362), unemployment rate and median household income (-0.625), and median household income and insurance status (0.583). Education level was correlated with a median household income at most of the levels included (less than 9th grade -0.494, 9th to 12th grade -0.801, high school graduate -0.768, bachelor's degree 0.837, and graduate degree 0.705). The unemployment rate was correlated with some of the education levels

(9^{th} -12^{th} grade 0.431, high school graduate 0.397, and bachelor's degree -0.370). The median age was significantly correlated with education at most of the levels included (less than 9th grade 0.384, 9th to 12th grade 0.494, high school graduate 0.575, bachelor's degree -0.535, and graduate degree -0.639). The proportion with health insurance was correlated with most of the levels of education included (less than 9th grade -0.610, 9th to 12th grade -0.546, high school graduate -0.368, bachelor's degree 0.575, and graduate degree 0.576).

Table 4 contains the results of the individual and multivariable-adjusted regressions. In the individual regression models, five variables were significant, and those variables were then placed into multivariable-adjusted regression. For the significant individual regressions there was age; an average county age that was one year higher was associated with 13 per 100,000 greater excess mortality (β=13.61 p-value=0.0045, CL=4.50 – 22.77). Then there was the unemployment rate; a 1 percent greater unemployment rate per county was associated with a 15 per 100,000 greater excess mortality (β=15.07 p-value=0.0169, CL=2.86 – 27.27). Then there was insurance status; a 1 percent greater proportion with health insurance per county was associated with a 21 per 100,000 lower excess mortality (β= -20.94 p-value=0.0090, CL=-36.35 – (-5.54)). Then there was median household income; an average county median household income that 1,000 dollars higher was associated with 6 per 100,000 lower excess mortality (β= -5.953 p-value <.0001, CL=-8.16 – (-3.75)). Then there was the race of Asian; a 1 percent greater proportion of county identified as Asian was associated with 50 per 100,000 lower excess mortality controlling for all other races/ethnicities included (β= -50.49 p-value = 0.0027, CL=-82.24 – (-18.74)). In the multivariable-adjusted regression, only median income was significant. An average county median household income that 1,000 dollars higher was associated with 4 per 100,000 lower excess mortality, controlling for median age, unemployment rate, insurance status, and race/ethnicity (β= -4.49 p-value =0.0483, CL=-8.95 – (-0.036)). No effect modification was found between the variables in the multivariable-adjusted regression (all p-values for interaction >0.05).

DISCUSSION

In the adjusted analysis, median household income was the only socioeconomic factor that was associated with differences in Covid-19 excess mortality across counties in Alabama. Several other factors that were individually predictive of Covid-19 excess mortality that are no longer predictive when included in the multivariable-adjusted model. This may be explained by the following correlations. The negative correlation between age and median income is not surprising because as the median age of a county increases, it could indicate that a higher proportion of the county is retired and no longer earning wages. The negative correlation between income level and the unemployment rate is explained by the fact that as the county unemployment rate goes up, average income would decrease. The moderate positive correlation between average income and insurance status can be explained by the ability of most people to get health insurance through work, and a higher average income indicates a higher employment rate.

A simulation study by Seligman at the individual level found that as income level and education level rose, the odds of mortality from Covid-19 decreased.[12] While our ecological county level analysis did not capture the effect education may have on excess mortality, we also found an association between income and Covid-19 excess mortality. The lack of association with education level at the county level may be due to the correlation between income level and education level. The Ackley paper indicates that the rurality of an area was associated with the amount of excess mortality. Our study did not find rurality to be a significant factor; this could be due to limited variation in rurality classification within Alabama. Although we used the same 4-level classification system, only 2 levels were represented by counties in our study (Metro and Micro areas) because Alabama does not have counties with the population levels of counties in California or New York .[15]. The Albitar paper found that age was risk factors for mortality for Covid-19 patients.[6] We made a similar observation for county median age in unadjusted analyses, but this association was no longer statistically significant in adjusted models.

The broader implication of this study is that socioeconomic factors were associated with excess mortality during the Covid-19 pandemic and possibly future pandemics and other health emergencies. To avoid preventable deaths, we need to fully understand the extent to which and why this occurs.

A major strength of this study is that the excess mortality outcome does not rely on the accuracy of death certificates and testing results or availability. The limitations of this study are that it is an ecologic analysis at the county level and does not allow for the consideration of individual comorbidities or other factors that affect Covid-19 mortality. Another limitation is this study is only representative of Alabama and is not generalizable to most of the United States.

Median household income may be an important socioeconomic factor in determining Covid-19 excess mortality. As socioeconomic factors play an important role in the underlying health of a population, they could be used as a guide to determine those most at risk for negative health outcomes and be used to drive health policies and target resources in future pandemics and epidemics.

Table 1. Source of data used for analysis of characteristics associated with excess mortality in Alabama counties, 2020

Variable (at county level)	Use/ Measure	Retrieved from
Race/Ethnicity	Measured as a percentage of county population for each race/ ethnicity, these races and ethnic categories are mutually exclusive	American Community Survey 2019 5-year estimates
Rurality	The total population for each county from American Community Survey was recorded using the Health Resource and Services Administration definition of Metro vs. Micro areas	American Community Survey 2019 5-year estimates
Age (Average)	As a control variable because death from Covid-19 is mostly in higher age groups	American Community Survey 2019 5-year estimates
Income Level	Measured as a county-level household average	American Community Survey 2019 5-year estimates
Insurance Status	Measured as a percentage of the population that has health insurance	American Community Survey 2019 5-year estimates
Unemployment Rates	Measured as percent of unemployment in each county	American Community Survey 2019 5-year estimates
Education Level	Measured as a percent of the population for an education level, there are seven levels	American Community Survey 2019 5-year estimates
Covid-19 Excess Mortality Data	Measured as excess deaths per 100,000	Ackley Paper Appendix [15]

Table 2 *Characteristics of residents of Alabama counties and county clusters*

Variable	Total (N=40)
Total Population	
Mean ± SD	119,127 ± 119,832
Median, Min-Max	76,168 (46,862 - 659,680)
Median Age	
Mean ± SD	40.12 ± 2.75
Median, Min-Max	40.55 (31.90- 44.27)
Race	**Average Percent ± SD**
White	68.32% ± 17.09%
African American	24.18% ± 18.65%
Hispanic Latino	4.22% ± 3.15%
American Indian/Alaska Native	0.56% ± 0.63%
Asian	0.90% ± 0.83%
Two or more races	1.66% ± 0.66%
Education Level	**Average Percent ± SD**
Less than 9th Grade	5.22% ± 1.93%
9th to 12th Grade	10.87% ± 2.60%
High School Graduate	33.80% ± 5.59%
Some College	21.10% ± 1.98%
Associate's Degree	8.61% ± 1.40%
Bachelor's Degree	12.82% ± 5.20%
Graduate/Professional Degree	7.56% ± 3.34%
Rurality	**N(%)**
Metro Area	37(92.50%)
Micro Area	3(7.50%)
Unemployment Rate	
Mean ± SD	6.26% ± 2.13%
Median, Min-Max	5.68% (3.40% - 11.98%)
Median Household Income	
Mean ± SD	$47,049 ± $9,501
Median, Min-Max	$46,599 ($30,590 - $77,800)
Insurance Status Yes	
Mean ± SD	90.19% ± 1.66%
Median, Min-Max	90.20% (86.30% - 93.80%)
Observed Death	
Mean ± SD	1619.40 ± 1424.34
Median, Min-Max	1205.50 (635-8509)
Expected Deaths	
Mean ± SD	1391.03 ± 1263.35
Median, Min-Max	993 (558 - 7480)
Excess Death per 100,000	
Mean ± SD	216.98 ± 85.30
Median, Min-Max	214 (46 – 444)

Table 3

Correlation of Socioeconomic Factors Related to Excess Mortality (per 100,000) (N = 40).

Variables	Median Age	Unemployment Rate	Household Income	Insurance Status	White	African American	Hispanic/ Latino	American Indian/ Alaska Native	Asian	Two or More Races	Less than 9th Grade	9th -12th grade	High School Graduate	Some College	Associate Degree	Bachelor's Degree	Graduate Degree
Median Age	1																
Unemployment Rate	0.191	1															
Household Income	-0.362*	-0.625**	1														
Insurance Status	-0.202	-0.250	0.583**	1													
White	0.296	-0.630**	0.335*	0.024	1												
African American	-0.200	0.685**	-0.374*	0.039	-0.981**	1											
Hispanic/ Latino	-0.207	-0.498*	0.216	-0.383*	0.347*	-0.507*	1										
American Indian/ Alaska Native	0.249	0.052	-0.128	-0.250	0.165	-0.213	0.172	1									
Asian	-0.747**	-0.224	0.540*	0.371*	-0.188	0.127	-0.017	-0.206	1								
Two or More Races	-0.257	-0.376*	0.283	-0.099	0.262	-0.367*	0.410*	0.250	0.236	1							
Less than 9th Grade	0.384*	-0.046	-0.494*	-0.610**	0.255	-0.297	0.490*	0.214	-0.593**	0.0061	1						
9th -12th Grade	0.494*	0.431*	-0.801**	-0.546*	-0.207	0.240	-0.072	0.179	-0.699**	-0.299	0.670**	1					
High School Graduate	0.575**	0.397*	-0.768**	-0.368*	0.018	0.069	-0.306	0.305	-0.749**	-0.268	0.471*	0.728**	1				
Some College	-0.209	-0.099	0.266	0.048	0.202	-0.211	0.107	-0.340*	0.260	0.208	-0.244	-0.367*	-0.454*	1			
Associates Degree	0.066	-0.153	0.067	-0.261	0.305	-0.337*	0.297	0.065	-0.132	0.277	0.170	-0.00053	-0.134	0.331*	1		
Bachelor's Degree	-0.535*	-0.370*	0.837**	0.575**	-0.057	0.0047	0.075	-0.217	0.760**	0.196	-0.711**	-0.867**	-0.859**	0.182	-0.176	1	
Graduate Degree	-0.639**	-0.272	0.705**	0.576**	-0.178	0.131	-0.019	-0.257	0.858**	0.136	-0.707**	-0.813**	-0.847**	0.172	-0.217	0.928**	1

Note. *Correlation is significant at 0.05 level ** Correlation is significant at < 0.0001 level

Table 4 *Multivariable-adjusted Regression Analysis Predicting Excess Mortality (per 100,000)* (N = 40).

	Individual Regression			Multiple Regression		
Variable	**β**	***p*-value**	**95% CI**	**β**	***p*-value**	**95% CI**
Median Age (years)	13.61	0.0045	4.50 – 22.77	4.10	0.5769	-10.75 – 18.96
Unemployment Rate (percentage)	15.07	0.0169	2.86 – 27.27	-5.64	0.5526	-24.82 – 13.54
Insurance Status (percentage)	-20.94	0.0090	-36.35 – (-5.54)	-6.16	0.5888	-29.18 – 16.86
Median Household Income (by $1,000)	-5.953	<0.0001	-8.16 – (-3.75)	-4.49	0.0483	-8.95 – (-0.036)
White (percentage)	Ref	Ref	Ref	Ref	Ref	Ref
African American (percentage)	0.883	0.2606	-0.69 – 2.45	0.242	0.8160	-1.87 – 2.35
Hispanic/Latino (percentage)	-2.06	0.6551	-11.33 – 7.22	-2.96	0.6259	-15.21 – 9.30
American Indian/Alaska Native (percentage)	17.61	0.3917	-23.64 – 58.87	9.01	0.6533	-31.55 – 49.58
Asian (percentage)	-50.49	0.0027	-82.24 – (-18.74)	-10.92	0.6552	-60.36 – 38.52
Two or More Races (percentage)	-10.23	0.6426	-54.68 – 34.20	-10.52	0.6152	-52.82 – 31.78
Less than 9^{th} Grade (percentage)	7.17	0.4315	-11.15 – 25.49			
9^{th} -12^{th} Grade (percentage)	1.32	0.8816	-16.58 – 19.22			
High School Graduate (percentage)	1.67	0.7819	-10.48 – 13.81			
Some College (percentage)	Ref	Ref	Ref			
Associate's Degree (percentage)	-21.66	0.0656	-44.81 – 1.48			
Bachelor's Degree (percentage)	-2.96	0.7076	-18.89 – 12.97			
Graduate/Professional Degree (percentage)	-7.14	0.4900	-27.94 – 13.66			

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