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Short communication

Socioeconomic determinants of health and county-level variation in cardiovascular disease mortality: An exploratory analysis of Georgia during 2014–2016

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ABSTRACT

Since cardiovascular disease (CVD) represents the leading cause of death in the state of Georgia, we sought to describe the relationship between socioeconomic determinants of health (SDH) and CVD-related mortality in Georgia using publicly available population health and economic data. A multivariate regression model was estimated to examine physical inactivity, median household income, health insurance status, urban–rural status, and air quality on CVD mortality in Georgia between 2014 and 2016. We find that the median household income and annual average ambient concentrations of PM2.5 were the most significant factors in explaining CVD mortality. Lower levels of median household income and higher concentrations of PM2.5 were associated with higher CVD mortality rates. Leisure-time physical inactivity, health insurance status, and urban–rural status were not associated with worsened CVD-related mortality. As such, policies and interventions aimed at improving socioeconomic status in Georgia should be explored in an effort to positively impact CVD outcomes. Furthermore, this exploratory study could be extended for all counties in the U.S.

1. Introduction

Cardiovascular disease (CVD) represents the leading cause of death in the state of Georgia, accounting for over 20,000 deaths per year. CVD is also the leading cause of mortality in the United States (US), with approximately 610,000 annual deaths are attributed to CVD. Costs associated with CVD treatment in Americans are estimated to exceed USD 1 trillion by 2035 (RTI International, 2017). Consequently, a better understanding of those factors influencing CVD mortality remains crucial for healthcare policy development.

Enhanced appreciation of socioeconomic determinants of health (SDH) affecting CVD outcomes may aid in the creation of beneficial societal interventions (Havranek et al., 2015). For example, higher rates of physical inactivity may increase an individual's risk for developing CVD (Lakka and Bouchard, 2005). Rising healthcare costs also present a barrier to many struggling to afford health insurance coverage. Finally, growing epidemiological and clinical evidence suggest that poor air quality may be associated with worsened CVD outcomes (Brooks et al., 2010).

At the state level in Georgia, the relationship between key SDH variables and cardiovascular disease related mortality is important, but poorly described. Therefore, we sought to investigate the relationship between key SDHs and CVD-related mortality in the state of Georgia at the county-level using data obtained from the US Center of Disease Control and Prevention (CDC). Beyond its granularity, utilizing county-level data has the benefit of being publicly available for local and regional public health officials and stakeholders responsible for assessing the effectiveness of various policy tools and interventions.

2. Data and methods

To further assess the relationship between selected SDH and CVD outcomes, data was obtained from CDC for each of the 159 counties in the state of Georgia between 2014 and 2016. Cardiovascular disease death rates (*CVD*) were measured as the total number of deaths per 100,000 individuals between 2014 and 2016. Leisure-time physical inactivity (*Inactivity*) was measured as an age-adjusted (20+) percentage in 2014 that reported no leisure-time physical activity (during the past month) in the Behavioral Risk Factor Surveillance Survey. Median household income (*Income*) was recorded in thousands of US dollars

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Table 1
Descriptive Statistics for CVD Mortality and Risk Factors in the state of Georgia during 2014–2016. County names provided for extremes of each variable[5-9]. $p < 0.05$ defined as significant; NS = nonsignificant.

	Mean	Standard deviation	Maximum	Minimum	Univariable level of significance	Multivariable level of significance
CVD	271.91	43.52	414.6 – Jeff Davis	175.2 – Mcintosh		
Inactivity (%)	26.48	2.75	32.5 – Colquitt	19 – Cobb	$p < 0.001$	NS
Income (in $1,000)	42.51	11.75	97.9 – Forsyth	25.9 – Clay	$p < 0.001$	$p < 0.001$
NoIns (%)	16.77	2.78	27.6 – Echols	10.4 – Harris	$p = 0.04$	NS
AirQ (μg/m^3)	10.74	0.62	12 – Fulton	8.7 – Towns	$p = 0.02$	$p < 0.001$
Urban (1, 0)	0.18	0.39	1	0	$p < 0.001$	NS

during 2015. The lack of health insurance (*NoIns*) was measured as an age-adjusted (under 65) percentage in 2015. Air quality (*AirQ*) was collected as annual average ambient concentrations of particulate matter that are less than or equal to 2.5 μm (PM2.5) in 2014 (U.S. Environmental Protection Agency, 2018). Urban-rural status (*Urban*) was categorized according to the US Census Bureau (2013) as large (central or fringe) metro areas (*Urban* = 1) or not (*Urban* = 0).

Table 1 depicts descriptive statistics for each variable included in this analysis. The average physical inactivity rate per county in Georgia was 26.5%, which is above the national average of 25.3% (America's Health Ranking United Health Foundation, 2015). Within the state of Georgia, there is substantial inter-county variability, with Cobb county demonstrating the lowest physical inactivity rate (19%), and Colquitt county demonstrating the highest (32%). According to the US Census Bureau, in 2015 the average median household income level for the state of Georgia was approximately $42,510, while the US national average was $53,657 (Denavas-Walt and Proctor, 2015). Similar to physical inactivity, there is considerable county-level income variability across Georgia. Forsyth county recorded the highest median household income level ($97,900/year), while Clay county had the lowest ($25,900/year).

In the United States, 10.4% (33.0 million) of Americans were without health insurance in 2014, while the average percentage of the population without health insurance in Georgia was 16.77% (Smith and Medalia, 2015). Echols county had the highest percentage of uninsured population (27.6%), while Harris county had the lowest (10.4%). Air quality as measured by particle pollution, a mixture of liquid droplets and solid particles, varies by county (U.S. Environmental Protection Agency (n.d.)). US air quality in concentrations of PM2.5 was recorded at 8.806 μg/m^3 in 2014; however, the average annual ambient concentrations of PM2.5 in Georgia was 10.74 μg/m^3. Fulton county had the worst air quality in Georgia with its concentrations reaching 12 μg/m^3, while Towns county had the best with its concentrations measuring 8.7 μg/m^3. Finally, urban–rural status controlled for counties that are considered large metro areas. There were 28 of the 159 counties in Georgia that were considered large metro areas with Fulton county being the largest.

3. Results

To assess the potential relationship between these SDH variables and CVD-related mortality, Stata/SE 15.1® was used to perform bivariate and multivariate regression (Table 1).

In the bivariate case of *CVD* and *Inactivity*, there is a statistically significant ($p < 0.001$) positive correlation between these two variables. As the percentage of leisure time physical inactivity increases, total cardiovascular mortality also increases at a rate of 7.3 (95% CI 5.1, 9.5) deaths per 100,000 for every 1% increase in the inactive population. Likewise, a statistically significant ($p < 0.001$) negative correlation was observed between *CVD* and *Income*. As median household income level increases by every $1,000, CVD mortality decreases by approximately 2.1 (95%CI −2.6, −1.6) deaths per 100,000 people. We observed a statistically significant ($p = 0.02$) positive correlation between *CVD* and *AirQ*. For every 1.0 μg/m^3 increase in average ambient concentrations of PM2.5, cardiovascular mortality increased by 13.4 (95% CI 2.5, 24.2) deaths per 100,000 people. Similar to *Inactivity* and *AirQ*, there is a statistically significant ($p = 0.04$) positive correlation between *CVD* and *NoIns*, with CVD deaths increasing by 16.77 per 100,000 for every 1% increase in uninsured rate. When county-level cardiovascular disease mortality rates are compared by urban–rural status, there is a significant difference between the two groups of 33.2 deaths per 100,000 ($p < 0.001$). On average, counties in the designated urban area (i.e., large metro areas) have lower cardiovascular disease mortality rates compared to the designated rural areas (i.e., medium metro areas and non-metro areas).

To further examine the significance of these variables, a multivariate regression model was estimated using CVD mortality as the dependent variable and each of the previously assessed SDH factors as its predictive variables. Specifically, the estimated multiple regression model is as follows:

$$CVD = 133.9 + \underset{(p=0.07)}{2.2\,Inactivity} - \underset{(p<0.001)}{2.1\,Income} - \underset{(p=0.12)}{1.8\,NoIns} + \underset{(p<0.001)}{18.6\,AirQ} - \underset{(p=0.56)}{5.0\,Urban}$$

The model's adjusted R^2 value = 0.41, and its F-statistic ($F = 23.34$; $p < 0.001$) support the model's capacity to predict cardiovascular disease-related mortality in Georgia between 2014 and 2016. Further, the average variance inflation factor (VIF) was 1.6 with each respected variable's VIF below 2.5 indicating little evidence of multicollinearity.

4. Discussion

This study demonstrates that several SDH variables that are easily and reproducibly assessed are associated with worsened cardiovascular outcomes in Georgia. In this analysis, both median household income and ambient air quality levels in concentrations of PM2.5 were associated with significantly worsened cardiovascular mortality between 2014 and 2016. Surprisingly, health insurance status was not significantly associated with increased cardiovascular mortality during the same timeframe. Neither was physical inactivity nor urban–rural status, suggesting that cardiovascular mortality during this timeframe was not significantly influenced by these measures. This highlights the need for multivariate over univariate analysis as there are potential confounding variables that need to be controlled for when examining CVD mortality. Univariate analysis may mislead public health officials as to what factor may lower CVD mortality.

When examining the SDH variables included in this model, median household income perhaps represents the widely influenced variable. Individuals with lower income levels contend with structural challenges that may contribute to poorer health and clinical outcomes. Lower median income may disadvantage an individual in numerous ways as it pertains to cardiovascular health. These may include reduced access to healthier, more costly foods; availability of recreational space and activities; and the capacity to pay for medical treatments and medications independent of insurance status.

Worsening air quality represents another significant factor as it relates to cardiovascular mortality. In 2018, Atlanta was ranked 23rd and

22nd most polluted city by ozone and by year-round particle pollution, respectively (American Lung Association (n.d.)). Contributing to this ranking would be population density and heavy traffic rates in the metro Atlanta area. In order to combat this problem, state representatives have discussed tax credits for electric car purchases to decrease gasoline emission of toxic chemical vapors. Such a tax credit could positively impact residents and improve their health. Policy proposals that promote other routes of transport such a paved roads or pathways that encourage walking or cycling would further reduce particle pollution as well as having the added benefit of increased physical activity reducing CVD mortality rates.

There were several limitations to this study. First, cardiovascular health is affected by numerous variables occurring over a time period longer than this study period. While variables such as income levels, health insurance status, and urban–rural status may not change much during this time period, this study provides evidence of how these variables are correlated with CVD mortality rates. Extending these results to a longer timeframe would further add to this study's findings. Additionally, the results from Georgia could also be compared and extended to the United States to examine the effects of state-specific policies and national-level policies. In this analysis, we opted to include variables that were accessible, accurate and would be informative for public health officials in formulating policy; however, we acknowledge that future expansion of our analysis could include additional variables that may influence CVD outcomes. Finally, in an effort to address the potential omitted variable bias (from univariate analysis), independent variables utilized in this analysis were both continuous and binary in nature. Consequently, possible measurement error may be associated with the binary variable (i.e., Urban) as some variation may be lost in the different degrees of urban–rural status at the county level. This potential measurement error might slightly bias our models towards retaining continuous variables, while omitting binary variables.

5. Conclusions

In multivariable modeling, lower household median income and worsened air quality were associated with worsened CVD outcomes in Georgia at the county level during 2014–16. Future studies examining the impact of these and other SDH variables upon cardiovascular outcomes in Georgia and beyond appear warranted.

CRediT authorship contribution statement

Sanjana Adepu: Software, Formal analysis, Writing - original draft. **Adam E. Berman:** Conceptualization, Writing - review & editing. **Mark A. Thompson:** Conceptualization, Methodology, Supervision, Writing - review & editing.

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