COVID-19 and health inequality: the nexus of race, income and mortality in New York City

Farzaneh Khayat, Lemir Teron and Farzin Rasoulyan

Abstract

Purpose – *The purpose of this paper is to evaluate socioeconomic factors related to COVID-19 mortality rates in New York City (NYC) to understand the connections between socioeconomic variables, including race and income and the disease.*

Design/methodology/approach – *Using multivariable negative binomial regression, the association between health and mortality disparities related to COVID-19 and socioeconomic conditions is evaluated. The authors obtained ZIP code-level data from the NYC Department of Health and Mental Hygiene and the US Census Bureau.*

Findings – *This study concludes that the mortality rate rises in areas with a higher proportion of Hispanic and Black residents, whereas areas with higher income rates had lower mortality associated with COVID-19, among over 18,000 confirmed deaths in NYC.*

Originality/value – *The paper highlights the impacts of social, racial and wealth disparities in mortality rates. It brings to focus the importance of targeted policies regarding these disparities to alleviate health inequality among marginalized communities and to reduce disease mortality.*

Keywords *COVID-19, Morbidity, Social inequality, Health disparities, New York City*

Paper type *Research paper*

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Introduction

By the end of February 2021, there have been more than 113 million confirmed COVID-19 infections and over 2.5 million deaths globally (Johns Hopkins Coronavirus Resource Center, 2020). In the USA, NY City became the early epicenter of the disease with over 227,400 total cases and more than 23,600 deaths (which includes confirmed and probable deaths) by mid-August 2020 and according to preliminary analysis by the New York City (NYC) Department of Health and Mental Hygiene (DOHMH) age, race and income all influence survival rates (Figure 1)(COVID-19: Data Totals – NYC Health, 2020). This is in alignment with a long body of evidence which has shown that health disparities and associated medical costs are uneven along racial and other socioeconomic lines. Access to care, family income, perceptions within the medical community and environmental factors including the pervasiveness of pollution hotspots in marginalized communities all contribute to public health inequality (Krieger *et al.*, 2005; Laveist, Gaskin and Richard, 2011; Gaskin *et al.*, 2014; Kimmel *et al.*, 2016; Teron *et al.*, 2019; You *et al.*, 2020). Our work evaluates COVID-19 morbidity and mortality to analyze whether public health disparities that broadly exist within the United States are also associated with this disease. We evaluate New York City to do so.

According to preliminary data released by the NYC DOHMH (COVID-19: Data Totals – NYC Health, 2020; Mays and Newman, 2020), the coronavirus is killing Black Americans and Hispanic people at twice the rate of whites in NYC. (Figures 2 and 3).

Received 4 May 2021
Revised 22 May 2021
Accepted 25 May 2021

Figure 1 COVID-19 deaths by race in New York City (Rate per 100,000 people)

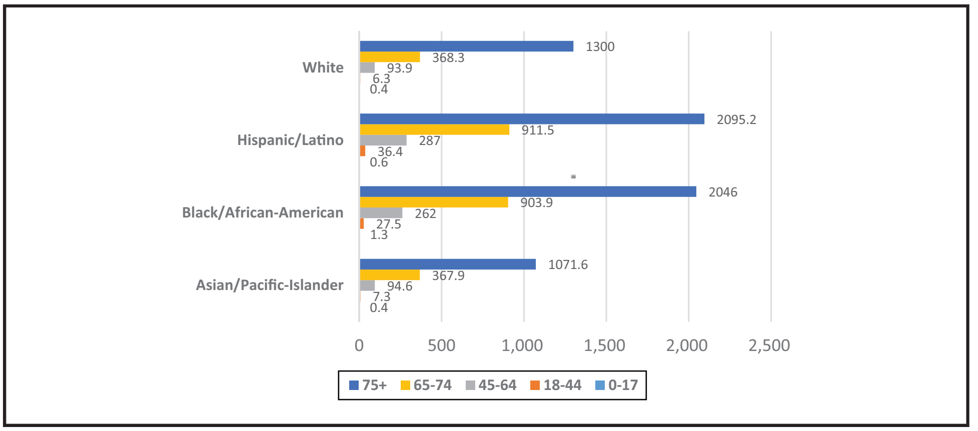


Figure 2 COVID-19 deaths by borough in New York City (Rate per 100,000 people)

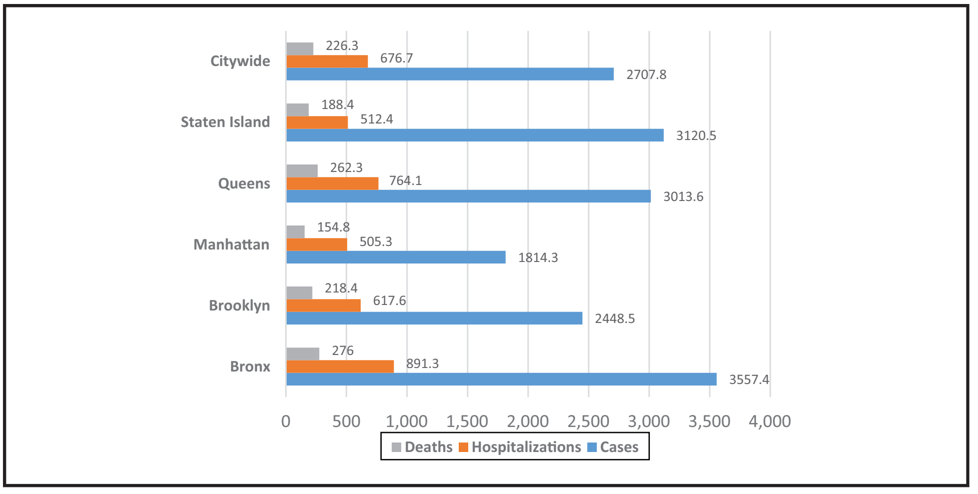
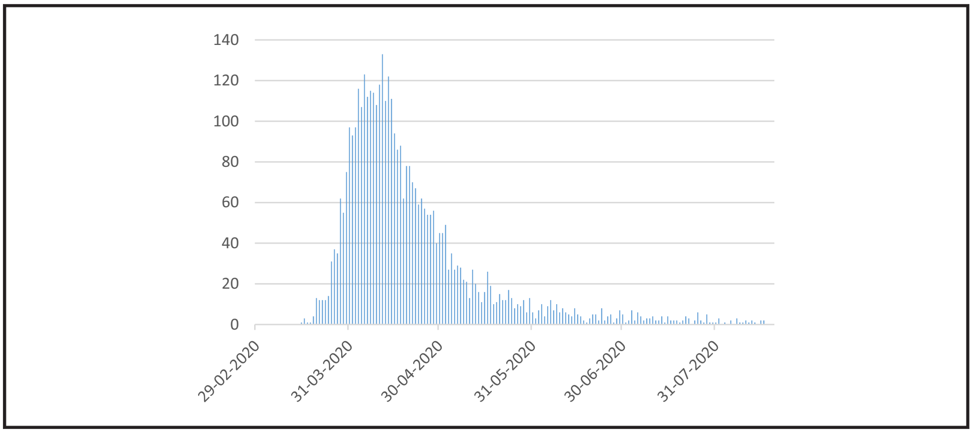


Figure 3 New York City's daily death counts (February 29 to 17 July 2020)



The socioeconomic and environmental contexts in which COVID-19 operates necessitates an understanding of how demographic related inequality can influence exposure, morbidity and mortality. Evidence shows that exposure to hazardous air pollutants contributes to COVID-19 morbidity (Petroni *et al.*, 2020) and that Blacks, overall, suffer from higher COVID mortality rates (Golestaneh *et al.*, 2020). Within NYC, citywide death rates for Hispanic (3273.2) and Black (3214.7) populations are more than double that of White (1,750) and Asian (1,538) populations (COVID-19: Data Totals – NYC Health, 2020) (Figure 1). It is pertinent to explore the disease within the context of race given high profile commentary by public officials that sought to pathologize COVID-19 disparities, risk and infection around personal hygiene and race along with appeals for personal responsibility, as opposed to comprehensively addressing public health barriers and structural inequality that may expose communities of color to disproportionate consequences from COVID-19 and other diseases.

Race, age and income

There is little doubt that there are racial and socioeconomic dimensions to health inequality in the USA; this is reflected in disparities in all-cause mortality rates (Krieger *et al.*, 2005; Kimmel *et al.*, 2016; Kochanek *et al.*, 2019); premature mortality (Mansfield *et al.*, 1999; Kiang *et al.*, 2019); all cancer death rates (DeLancey *et al.*, 2008; Siegel *et al.*, 2011), cervical cancer incidence (McDougall *et al.*, 2007), infant mortality (Mage *et al.*, 2019) and pregnancy-related mortality among Black Americans (Vilda *et al.*, 2019). Income inequality is also a factor associated with mortality disparities. A ten year study among adults over the age of 50 years old indicated the most-disadvantage quartile had a 2.8 times higher mortality risks compared to the least disadvantaged quartile in the USA (Nandi *et al.*, 2014). Shaw *et al.* (2014), note that health inequality persists as Americans age, even among the states with the highest welfare rates. It is noteworthy that socioeconomic disparities on health and mortality in elderly populations may be a function of inequalities that were formed much earlier in life, as accumulated harmful impacts can compound over time (Shaw *et al.*, 2014); this complicates tracking health problems amongst vulnerable populations. Meanwhile, along with race and income, an inverse relationship between neighborhood economic status and all mortality rates (Mode *et al.*, 2016) illustrates the burdens that low income communities face.

Materials and methods

This study contributes to health disparities literature by examining socioeconomic factors and COVID-19 mortality rate in NYC. We hypothesized mortality disparities due to the COVID-19 pandemic can be accounted for by race, median household income and age. The hypotheses are as follows:

- *H1*. Blacks and Hispanics are more likely to die due to COVID-19 compared to Whites.
- *H2*. Lower median household income is related to the higher likelihood of COVID-19 mortality.
- *H3*. Age is associated positively with the number of deaths of COVID-19 in different areas.

Materials

The NYC DOHMH has collected data on people who have tested positive for COVID-19 along with related hospitalizations and death rates. Data is categorized by the patients' age, race, sex and ZIP code across the city (COVID-19: Data Totals – NYC Health, 2020). Information was available on a daily basis since February 29, 2020, and the mortality rate in this research accounted for 140 days through July 17, 2020 (the 17th was the day that the number of new COVID-19 death and hospitalization became zero for the first time after the pandemic hit NYC). Using data provided by DOHMH, 216,468 cases were positive, including 55,515 hospitalizations and 18,720 confirmed and 4,616 probable deaths. Data related to the variables that we used were all collected from the US Census Bureau, American Community Survey 5-Year Data Profiles (2018).

Methods

Research model

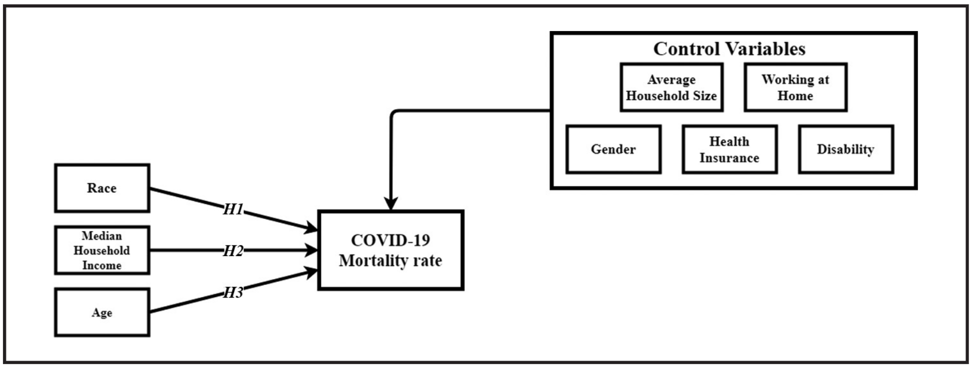
Based on the descriptions in the literature review and our hypothesis, we use three variables (age, race and median household income) as our independent variables. Besides the independent variables, several control variables were added: gender, average household size, percent of people having insurance (public or private), percent of people working at home and percent of people with a disability are controlled in our model in order to explain a great proportion of the variations of the dependent variable and in order to decrease the bias in the results for intended coefficients. Also, we controlled for the variations of boroughs by adding a categorical variable "Borough" to our model. Our model is as follows: (Figure 4):

$$\text{Death rate} = f\,(\text{Age, Race, Median household income, Controls})$$

With the objective to better understand the relationship between health and mortality disparities related to COVID-19 and socioeconomic conditions, we employed a multivariable negative binomial regression statistical method with three statistical significances ($p < 0.01$, $p < 0.05$, $p < 0.1$). We chose this method because the dependent variable consists of non-negative integer values. Negative binomial regression is based on the Poisson-gamma mixture distribution and is useful for predicting count data. Our dependent variable (COVID-19 death rate) has a non-normal, highly skewed (Skewness = 1.149) and highly kurtotic (Kurtosis = 5.490) distribution. The Shapiro–Wilk test (z = 4.897) and Jarque–Bera normality test (χ^2 = 83.24) both rejected the normality of the dependent variable. Because of the non-normal distribution and non-continuous nature of the dependent variable, multiple linear regression is not suitable for our analysis. From here, the first choice is Poisson regression; however, in the Poisson distribution the mean and the variance are equal, which is not satisfied for our dependent variable (mean = 210.703, variance = 12237.29). This over-dispersion, which is caused by heterogeneity among observations, could be resolved by adding a gamma-distributed error term to the Poisson distribution. Therefore, we use a negative binomial regression method in our analysis. Analyses were conducted using Stata/MP software.

We used a series of demographic categories (race, median household income and age) and created a null hypothesis that socioeconomic factors have no effect on the mortality rate during the pandemic in NYC. This was done in order to identify the nexus between coronavirus death disparities and socioeconomic inequality among over 18,000 confirmed deaths in NYC. As we used "Mortality rate per 100k people" as our dependent variable, there was no need to include the population as an exposure variable in our model. The main variables used in our model are as follows: race, age, percentage of people working at home, the percentage of people with health insurance coverage, average household size and disability status.

Figure 4 Conceptual model



Results

Descriptive statistics and pairwise correlations

Table 1 provides an overview of the descriptive statistics of the variables in this study. Except for the death rate of COVID-19, average household size and median household income, the other variables are in the percentages. Median household income is transformed via logarithm. The mean number of deaths across ZIP codes is 210.7 deaths per 100,000. Death vary widely across ZIP codes with a minimum of 23.8 and a maximum of 716.8; this disparity clearly demonstrates the disproportionate burden of COVID-19 and death rates amongst different ZIP codes in NYC.

The pairwise correlations from the above mentioned variables illustrates a significant positive correlation between death rate and the following variables: percent of Black population (r = 0.37, $p < 0.01$), percent of Hispanic population (r = 0.31, $p < 0.01$), percent of population under 18 (r = 0.37, $p < 0.01$), average household size (r = 0.34, $p < 0.01$) and percent of population with a disability (r = 0.44, $p < 0.01$) (Table 2).

Negative binomial regression analysis

Table 3 represents the estimates of model parameters (β), standard errors of these estimates, mortality rate ratios (MRR), 95% confidence intervals for both β and MRR and goodness of fit statistics such as logarithmic likelihood and pseudo R-squared. The alpha measure tests whether or not we should have used the negative binomial regression analysis instead of Poisson regression. The LR test of alpha = 0 is rejected (Prob >= χ^2 = 0.000), then the mean and the variance of the dependent variable is not equal, which

Table 1 Descriptive statistics

Variable	*Obs*	*Mean*	*SD*	*Min*	*Max*	*25th*	*50th*	*75th*
Death Rate	174	210.703	110.622	23.82	716.97	136.55	198.005	265.15
White percent	174	46.581	25.949	1.8	98.7	22.7	46.8	67.9
Black or African American percent	174	21.766	25.06	0	92.6	3.2	9.35	34.4
Hispanic or Latino percent	174	25.849	19.343	1.1	75.8	10.9	18.9	37.1
Sex ratio (Male percent)	174	47.757	2.798	34.5	59.3	46.2	47.8	49.4
Under 18 (percent)	174	19.771	5.700	0	36.2	16.8	20.1	23.2
Over 65 (percent)	174	14.842	7.053	1.3	80.8	11.1	13.75	17.3
Worked at home (percent)	174	4.167	2.399	0.4	14.9	2.4	3.4	5.2
With health insurance coverage (percent)	174	92.411	3.85	76.2	100	90.5	93.1	95.1
Average household size	174	2.63	0.513	1.38	3.97	2.25	2.67	2.96
With a disability (percent)	174	10.613	4.176	1.4	41.6	8.4	9.9	12.3
Log (Median Household Income) in dollars	174	11.094	0.451	9.96	12.43	10.84	11.10	11.37

Table 2 Correlation matrix

Variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*
(1) Death Rate	1												
(2) White	−0.46*	1											
(3) Black or African American	0.37*	−0.75*	1										
(4) Hispanic or Latino	0.31*	−0.41*	0.38	1									
(5) Gender	−0.16	0.14	−0.38*	0.21*	1								
(6) Under 18	0.37*	−0.42*	0.33*	0.41*	0.40	1							
(7) Over 65	0.11	0.30*	−0.167	−0.31*	−0.45*	−0.41*	1						
(8) Worked at home	−0.48*	0.46*	−0.30*	−0.24*	−0.19	−0.51*	0.27*	1					
(9) With health insurance coverage	−0.35*	0.54*	−0.12	−0.61*	−0.24*	−0.33*	0.35*	0.42*	1				
(10) Average household size	0.34*	−0.53*	0.28*	0.37*	0.25*	0.70*	−0.30*	−0.68*	−0.52*	1			
(11) With a disability	0.44*	−0.18	0.23*	0.29*	−0.42*	0.09	0.56*	−0.00	0.00	−0.02	1		
(12) Log (Median Household Income)	−0.53*	0.64*	−0.41*	−0.64*	0.14	−0.53*	0.12	0.40*	0.60*	−0.38*	−0.55*	1	
(13) Borough	0.23*	−0.13	0.15	−0.16	0.04	0.35*	0.02	−0.40*	−0.26*	0.46*	0.00	−0.17	1

Note: $^{*}p < 0.01$

Table 3 Estimation results of negative binomial regression

Variables	(1) Estimate	(2) Std err	(3) 95% CI of β	(4) MRR	(5) 95% CI of MRR	(6) p-value
White	−0.00530**	(0.00257)	(−0.1034 _ −0.0003)	0.995	(0.990 – 1.000)	0.039
Black	0.00332	(0.00218)	(−0.0010 _ 0.0076)	1.003	(0.999 – 1.007)	0.128
Hispanic	0.00455*	(0.00263)	(−0.0006 _ 0.0096)	1.005	(0.999 – 1.010)	0.084
Gender	0.0265*	(0.0152)	(−0.0033 _ 0.0564)	1.027	(0.997 – 1.059)	0.081
Under 18	0.0394***	(0.00902)	(0.0217 _ 0.0571)	1.040	(1.022 – 1.059)	0.000
Over 65	0.0409***	(0.00843)	(0.0243 _ 0.0574)	1.042	(1.025 – 1.059)	0.000
Worked at home	−0.0715***	(0.0168)	(−0.1045 _ −0.0385)	0.931	(0.901 – 0.962)	0.000
With health insurance	−0.0346***	(0.0131)	(−0.0603 _ −0.0089)	0.966	(0.941 – 0.991)	0.008
Average household size	−0.260**	(0.114)	(−0.4840 _ −0.0356)	0.771	(0.616 – 0.965)	0.023
With a disability	0.0298**	(0.0141)	(0.0021 _ 0.0575)	1.030	(1.002 – 1.059)	0.035
Log(Median household income)	0.200	(0.142)	(−0.0786 _ 0.4786)	1.221	(0.924 – 1.614)	0.159
Borough	0.0307	(0.0247)	(−0.0.176 _ 0.0791)	1.031	(0.983 – 1.082)	0.213
Lnalpha	−2.160***	(0.111)				
Pseudo-R^2	0.0753					
Log likelihood	−972.16246					
Observations	174					

Notes: The dependent variable is COVID-19 mortality rate per 100k. MRRs, Mortality rate ratios. Standard errors in parentheses ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

means that negative binomial regression is appropriate to use. Our model explains 7.53%of the variations of the COVID-19 mortality rate (Pseudo-R^2 = 0.0753). Coefficient estimates represent how a one-unit increase in the independent variable will increase the expected log count of the dependent variable. For example, a 1% increase in the white population in one of NYC's ZIP codes will significantly (p-value < 0.05) decrease the expected log count of the COVID-19 mortality rate in this area by 0.00530. MRR represents how a one-unit increase in the independent variable will increase/decrease the rate of the dependent variable (Table 3). For example, a 1% increase in the Hispanic population in one ZIP code will significantly (p-value < 0.1) increase the rate of the mortality per 100k by 0.4%.

Considering race as the first independent variable, while the percent of Black people does not have a significant relationship with the death rate, the percentage of White and Hispanic residents associates significantly with the number of deaths. The percentage of Whites associates negatively (MRR = 0.995, 95% CI 0.990-1, p = 0.039) and the percentage of Hispanics associates positively (MRR = 0.995, 95% CI 0.990-1, p = 0.084) with the COVID-19 mortality rate. The mortality rate is significantly higher among Blacks (χ^2 = 20.2, Prob > χ^2 = 0.0000) and Hispanics (χ^2 = 7.76, Prob > χ^2 = 0.0053) than that of Whites. However, there is no significant difference between the death rates of Black and Hispanic. The results from this first regression provides support for our first hypothesis that Black and Hispanic residents are more likely to die due to COVID-19 compared to Whites and the mortality rate of COVID-19 has a significant positive association with race in NYC.

Regarding median household income as the second independent variable, the result suggests median household income does not have a significant association with the number of deaths (p = 0.159), therefore the second hypothesis is not supported. With regards to the third hypothesis, the results illustrate that in areas with a higher percent of people over 65 and a higher percent of people under 18, the death rate is on average greater, significantly. Every percent increase in the population over 65 increases the expected log count of the mortality rate by 0.0409 (β = 0.0409, 95% CI 0.0243 _ 0.0574, p = 0.000). And every percent increase in the population under 18 increases the expected log count of the mortality rate by 0.0394 (β = 0.0394, 95% CI 00.0217 _ 0.0571, p = 0.000).

Additionally, every percent increase in the male population significantly increases the rate of COVID-19 mortality by 2.7%(MRR = 1.027, 95% CI 0.997-1.059, p = 0.081). And increases in the population of disabled residents significantly increases the rate of COVID-19 mortality by 3% (MRR = 1.030, 95% CI 1.002-1.059, p = 0.035). However, average household size, the percentage of people working at home and the percent with health insurance associate negatively and significantly with the mortality rate of COVID-19. Every percentage increase in the population of people working at home (MRR = 0.931, 95% CI 0.901 − 0.962, p = 0.000) and with health insurance coverage (MRR = 0.966, 95% CI 0.941 – 0.991, p = 0.008) will decrease the mortality rate of COVID-19 by 6.9% and 3.4%, respectively. Finally, increasing average household size by one person will cause the expected log count of mortality rate to decrease by 0.260 (β = −0.260, 95% CI −0.4840 _ −0.0356, p = 0.023).

We included the interaction terms of "Borough" and independent variables to our model to test whether borough moderates the relationship between the three hypothesized variables and death rate. Results illustrate that the effects of logarithm of median household income on death rate changes significantly in different boroughs (p = 0.077). Furthermore, there is a significant difference in the relationship between percent of people over 65 and mortality rate in the different boroughs of NYC (p = 0.005). However, borough does not moderate the relationship between race variables and death rate. That is, the relationship between percentage of people with the three studied races and mortality rate do not differ significantly across boroughs.

Discussion

Many factors are associated with the prevention and control of infectious diseases. This study evaluated the relationships between age, race and household income and COVID-19 mortality to ascertain whether NYCs experience is in line with previous literature on socioeconomics, public health and mortality (Adhikari *et al.*, 2020; Mahajan and Larkins-Pettigrew, 2020; Wang *et al.*, 2020). Our study is in line with previous studies on racial disparities nationwide. Race-specific data on county level illustrates a positive correlation between the percentage of Blacks living in a county and COVID-19 confirmed cases and deaths across 2886 counties (92% of US counties) (Mahajan and Larkins-Pettigrew, 2020).

The multivariable negative binomial regression statistical test provided evidence that the median household income rate explains some variations of the mortality rate in the studied areas. Areas with higher income rates had fewer deaths per 100,000 people on average. Results concerning the relationship between deaths and higher concentrations of Hispanic and Black residents show that mortality rates rise in areas with higher percentages of those populations. Deeper investigation through regression analysis using controlling numerous factors (e.g. access to insurance) suggest that a multitude of factors inform death disparities, and that is race alone is not associated with excess deaths, particularly in Black ZIP codes. As this is shown in Table 2 (column 3) there is a significant positive correlation between percentage of Black population with average household size (r = 0.28, $p < 0.01$) and percentage of people with a disability, (r = 0.23, $p < 0.01$). Moreover, there is a significant negative correlation between percentage of Black population with percentage of people worked at home (r = 0.30, $p < 0.01$), and percentage of people with health insurance coverage (r = −0.12, $p < 0.01$), and median household income (r = −0.41, $p <$ 0.01). This mandates a deeper look at and understanding of the cumulative impacts of socioeconomic inequality.

The growth rate of COVID-19 cases and deaths was greater for the 100 largest American metropolitans with higher levels of racial segregation (Yu *et al.*, 2021) The association of racial and economic disparities with COVID-19 mortality indicates while income disparity has exacerbated racial segregation, the joint effect of these two factors has a synergistic effect on raising COVID-19 cases and deaths in these metropolitan areas (Yu *et al.*, 2021).

Disparities related to COVID-19 represent wider public health inequality, which is propelled by pervasive imbalances in health-care systems and amplified by economic and environmental factors. Absent addressing underlying racial, social and economic inequality, the potential to eliminate said disparities is nominal.

This study has also demonstrated that higher percentages of people working at home and larger percentages of people with health insurance significantly lowers death rates, further illustrating the socioeconomic aspects of exposure, as marginalized populations are disproportionately represented amongst frontline workers, including grocery stores, transportation service and health care (CDC, 2020; Dyal *et al.*, 2020; Hawkins, 2020). Additionally, the lack of work from home accommodations, not having paid sick days and needing to work when sick exposes these groups to higher risk of COVID infection (Gould and Wilson, 2020).

Demographic factors, including average household size may explain some variations in death across areas. Higher population densities, which manifests in sharing crowded spaces (U.S Department of Housing and Urban Development, 2007), can make it difficult to self-isolate and/or self-quarantine leading to more exposures to COVID-19 (CDC, 2020). Other factors like the percent of people with health insurance is found to be negatively associated with death rates, whereas the percent of people with disabilities are positively associated with death rates in NYC (CDC, 2020). Further, disability (as one of the social vulnerability factors) predicted COVID-19 cases in the USA (Karaye and Horney, 2020). There are some variations in mortality rates across boroughs that are not explained by the studied variables. In addition, the link between socio-economic factors and death rate is not the same for each borough. There may be structural differences in the boroughs that lead to the different results.

Along with being armed with the knowledge of how the virus spreads and best practices related to slowing the spread of the disease, it is critical that policy makers and public health officials be knowledgeable of the possible impacts that social, racial and wealth disparities play in mortality rates among residents. Our analysis suggests that there are socioeconomic influences on disease spread and mortality amongst NYC residents. It is imperative that the dynamics addressed in this research are understood by public health practitioners and researchers, particularly related to efforts that seek to eliminate health disparities that negatively influence the livelihoods of marginalized populations and communities. Because vulnerability is compounded by a host of factors that include environmental (Brulle and Pellow, 2006), diet (Méjean *et al.*, 2013), poverty (Sabanayagam and Shankar, 2012), lack of access to education and health services (Wagstaff and Watanabe, 2002; Krieger *et al.*, 2005; Benach, 2020); we also see a strong nexus with environmental justice efforts – which seeks to alleviate disparities and create healthy living conditions for all communities and environments – in NYC and beyond. Because of gaps that cities, including NYC, have given to environmental justice and racial equality concerns, along with gulfs of engagement with linguistically isolation households and residents (Teron, 2015; Teron, 2016); it is vital that these factors be considered in concert with public health efforts to reduce disease mortality.

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