

**Test file:** Socioeconomic Determinants of COVID-19 Mortality in Metropolitan Areas: A Multilevel Analysis

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## Abstract

This multilevel study investigates socioeconomic predictors of COVID-19 mortality across 50 metropolitan areas. Neighborhood-level poverty, household crowding, and racial composition significantly predicted mortality rates after adjusting for individual-level factors. The results highlight structural determinants of pandemic outcomes.

**Keywords:** COVID-19; Social Determinants of Health; Health Equity; Multilevel Analysis; Mortality; Pandemic Response

## 1. Introduction

The COVID-19 pandemic has exposed and exacerbated existing health inequities, with marginalized communities experiencing disproportionately higher mortality rates [1]. While individual risk factors for severe COVID-19 outcomes are well-established, the role of neighborhood-level socioeconomic factors remains less understood. Understanding these contextual determinants is crucial for developing equitable pandemic response strategies [2].

Multilevel modeling provides an appropriate framework for examining how both individual characteristics and neighborhood contexts jointly influence health outcomes [3]. Previous studies have documented associations between area-level deprivation and COVID-19 outcomes, but few have comprehensively examined multiple socioeconomic dimensions across diverse metropolitan settings [4,5]. This study aims to address this gap by investigating the independent effects of neighborhood-level socioeconomic factors on COVID-19 mortality, while controlling for individual-level risk factors.

## 2. Methods

### 2.1 Study Design and Data Sources

We conducted a retrospective multilevel analysis using COVID-19 mortality data from 50 metropolitan statistical areas (MSAs) in the United States from March 2020 to December 2022. Data were obtained from state health departments, the U.S. Census Bureau, and the American Community Survey.

### 2.2 Study Population

The study included all confirmed COVID-19 cases with complete demographic and outcome data (n=2,847,392). Individual-level variables included age, sex, race/ethnicity, and pre-existing comorbidities. Neighborhood-level variables were constructed at the census tract level.

### 2.3 Variable Definition

The primary outcome was COVID-19 mortality. Neighborhood-level predictors included: 1)

poverty rate (percentage of population below federal poverty level), 2) household crowding (percentage of households with >1 person per room), 3) racial/ethnic composition, 4) educational attainment, and 5) healthcare access indicators.

## 2.4 Statistical Analysis

We fitted three-level random intercept models with individuals nested within census tracts, and census tracts nested within MSAs. Models were adjusted for individual-level covariates and metropolitan-area fixed effects. The intraclass correlation coefficient (ICC) was calculated to quantify between-neighborhood variance.

## 3. Results

### 3.1 Descriptive Statistics

The overall COVID-19 mortality rate was 1.8%. Substantial geographic variation was observed, with mortality rates ranging from 0.9% to 3.2% across MSAs. Neighborhood-level characteristics also showed wide variability, with poverty rates ranging from 2% to 45% across census tracts.

### 3.2 Multilevel Models

After adjusting for individual-level factors, neighborhood poverty rate (OR: 1.32, 95% CI: 1.18-1.47), household crowding (OR: 1.25, 95% CI: 1.12-1.39), and percentage of racial/ethnic minorities (OR: 1.28, 95% CI: 1.15-1.42) remained significant predictors of COVID-19 mortality. The ICC indicated that 18% of the variance in mortality was attributable to neighborhood-level factors.

### 3.3 Interaction Effects

Significant interactions were observed between individual-level race and neighborhood-level poverty. Racial minority individuals living in high-poverty neighborhoods had the highest mortality risk (OR: 2.45, 95% CI: 2.18-2.76) compared to white individuals in low-poverty neighborhoods.

## 4. Discussion

### 4.1 Principal Findings

Our analysis demonstrates that neighborhood-level socioeconomic factors significantly influence COVID-19 mortality risk, independent of individual characteristics. The findings highlight how structural determinants shape pandemic outcomes and contribute to health inequities.

### 4.2 Policy Implications

The results support targeted interventions in high-risk neighborhoods, including improved testing access, healthcare resources, and economic support. Pandemic preparedness plans should incorporate neighborhood-level vulnerability assessments to guide resource allocation.

### 4.3 Limitations

Limitations include potential misclassification of COVID-19 mortality and the ecological nature of neighborhood-level variables. Future research should incorporate longitudinal data and additional neighborhood characteristics.

## 5. Conclusion

This multilevel analysis provides robust evidence that neighborhood socioeconomic context significantly influences COVID-19 mortality risk. Addressing structural determinants through place-based interventions is essential for achieving health equity in pandemic response and

preparedness.

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