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Authors

Frochen, Stephen
Wong, Michelle S
Neil Steers, William
et al.

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Differential Associations of Mask Mandates on COVID-19 Infection and Mortality by Community Social Vulnerability

Stephen Frochen, PhD, MA (ORCID: 0000-0001-6613-2506),[a] Michelle S. Wong, PhD (ORCID: 0000-0001-7917-9696),[a] W. Neil Steers, PhD, [a] Anita Yuan, PhD,[a] Debra Saliba, MD, MPH (ORCID: 0000-0001-5177-6616),[a,b,c,d] and Donna L. Washington, MD, MPH (ORCID: 0000-0001-7917-4609) [a,e]

[a] VA Greater Los Angeles Healthcare System, Center for the Study of Healthcare Innovation, Implementation, and Policy (CSHIIP), Sepulveda Ambulatory Care Center
16111 Plummer St., Bldg. 25
North Hills, CA 91343.

[b] VA Greater Los Angeles Healthcare system, Geriatric Research, Education and Clinical Center
West Los Angeles Campus
11301 Wilshire Blvd., Bldg. 158
Los Angeles, CA 90073.

[c] Borun Center, University of California Los Angeles
UCLA Division of Geriatrics
10945 Le Conte Ave., Peter V. Ueberroth Bldg.
Los Angeles, CA 90095

[d] RAND Health

RAND Corporation

1776 Main St.

Santa Monica, CA 90401

[e] David Geffen School of Medicine, University of California Los Angeles

Geffen Hall

885 Tiverton Dr.

Los Angeles, CA 90095

Corresponding Author

Stephen Frochen, PhD, MA

VA Greater Los Angeles Healthcare System, Center for the Study of Healthcare Innovation, Implementation, and Policy (CSHIIP)

16111 Plummer St., Bldg. 25

North Hills, CA 91343.

stephen.frochen@va.gov.

(909) 319-7606.

Michelle S. Wong, PhD

michelle.wong6@va.gov.

W. Neil Steers, PhD

william.steers@va.gov.

Anita Yuan, PhD

anita.yuan@va.gov.

Debra Saliba, MD, MPH

saliba@rand.org.

Donna L. Washington, MD, MPH

donna.washington@va.gov.

Abstract

Background The COVID-19 pandemic in the U.S. has disproportionately impacted communities deemed vulnerable to disease outbreaks. Our objectives were to test 1) whether infection and mortality decreased in counties in the most vulnerable (highest) tercile of the Social Vulnerability Index (SVI), and 2) whether disparities between terciles of SVI were reduced, as the length of mask mandates increased.

Methods Using the New York Times COVID-19 and the CDC SVI and mask mandate datasets, we conducted negative binomial regression analyses of county-level COVID-19 cases and deaths from 1/2020 to 11/2021 on interactions of SVI and mask mandate durations. **Results** Mask mandates were associated with decreases in mid-SVI cases (IRR: 0.79) and deaths (IRR: 0.90) and high-SVI cases (IRR: 0.89) and deaths (IRR: 0.88). Mandates were associated with mitigation of infection disparities (Change in IRR: 0.92) and mortality disparities (Change in IRR: 0.85) between low and mid-SVI counties and mortality disparities between low and high-SVI counties (Change in IRR: 0.84).

Discussion Mask mandates were associated with reductions in COVID-19 infection and mortality, and mitigation of disparities for mid and high vulnerability communities.

Conclusion Ongoing COVID-19 response efforts may benefit from longer-standing infection control policies, particularly in the most vulnerable communities.

Key Words: COVID-19 Infection, Mortality, Social Vulnerability, Mask Mandates, Disparity Mitigation

Background

The COVID-19 pandemic has underscored disparities by social vulnerability in population health in the United States.[1] Social vulnerability refers to the socioeconomic and demographic factors that affect the ability of a community to respond to and recover from adverse events, such as disease outbreaks like the COVID-19 pandemic. As the pandemic's impacts have varied by time and geography, state and local governments have responded with health policy interventions that vary in the timing and extent of their rollout and retraction. Mask mandates, which governed the use of face masks in public areas to mitigate the spread of airborne infection, were one of the earliest COVID-19 policy interventions. While mask mandates are an effective tool in controlling COVID-19 infection, understanding whether mask mandates have reached the groups at greatest risk, particularly socially vulnerable communities that have been disproportionately impacted by COVID-19, is important.[2-3]

As part of its natural disaster, emergency, and disease outbreak preparedness efforts, the Centers for Disease Control and Prevention (CDC) developed the Social Vulnerability Index (SVI), to measure a community's public health risk and need for recovery assistance during and after an emergency like the pandemic.[4] Higher SVI for a community, indicating higher social vulnerability, is associated with greater levels of COVID-19 incidence and mortality.[4,5] Though prior studies have documented this relationship for cohorts limited by time (e.g., the initial few months of the pandemic) or by different geographic levels or regions, these studies have not considered whether the relationship between community-level social vulnerability and COVID-19 has changed over time and to what extent.[6-18] Such an examination can provide a better understanding of the unfolding nature of the pandemic in communities deemed more vulnerable to disease outbreaks by the CDC.

Further, and perhaps most importantly, it is critical to understand if public health policies, such as mask mandates, benefit high socially vulnerable communities to the same extent as less vulnerable communities to ensure that such policies do not unintentionally exacerbate disparities. Given that mask mandate policies changed over time and were developed and implemented by local governments, e.g., at the county level, geographic inequities existed in the protections they offered over time, a complicated relationship between COVID-19 outcomes and mask mandates that is understudied. Minimal research has investigated the protective association of mandates specifically in the most vulnerable communities,[19] which often contain higher proportions of older adults, racial and ethnic minority groups, and low-income essential workers more at risk for disease transmission and death during the pandemic.[10,20] Additionally, few studies have measured mask mandates as durations of time living under a mandate in order to test for changes in COVID-19 outcomes between shorter and longer standing mask policies.[2]

To fill these gaps in understanding, this paper examines relationships between mask policies and COVID-19 infection and mortality in the most vulnerable communities from January 21, 2020 to November 30, 2021. Our aims are: 1) to test whether mask mandates of longer duration are associated with decreases in COVID-19 infection and mortality in the most vulnerable communities, and 2) to determine whether mask mandates are associated with reductions in COVID-19 infection and mortality disparities between vulnerable and less vulnerable communities.

Methods

Data

The units of observation for this investigation are all U.S. counties. We used the following datasets: The New York Times GitHub county COVID-19 case and death dataset, and the U.S. Census 2020 county population dataset, the CDC/Agency for Toxic Substances and Disease Registry (ATSVR) 2018 SVI county-level dataset, the CDC county public mask mandate dataset, the Ballotpedia state mask policy survey dataset, and the Pandemic Vulnerability Index.[21-26] Information about mask mandates came from two datasets: As certain counties reported different mask policies relative to their respective states, the CDC mask mandate dataset was used to account for individual county mandates early on in the pandemic in states without mandates, and the Ballotpedia survey was used to fill in gaps in statewide mandate reporting, particularly following August 15, 2021 when the CDC mask mandate dataset ended. These datasets were linked by county FIPS codes and their variables homogenized to conform to the reporting practices of the New York Times GitHub COVID-19 data contributor team, including the merging of three pairs of Alaskan counties into three distinct reporting entities for statistical analysis, and the adjustment of anomalous case and death counts at the county level of analysis using imputed data.[27,28] The combined dataset charts daily COVID-19 cases and deaths and mask mandates from January 21, 2020, the date of the first recorded county-level case, to November 30, 2021, the end of the Delta surge. Reporting of infection and mortality by county was staggered into the dataset by date from early 2020 as counties began sequentially recording cases and deaths, reaching a full census by December 10, 2020.

Study Measures

Outcomes

Study outcomes are cumulative COVID-19 case and death counts per 100,000 population in counties from January 21, 2020 to November 30, 2021. These outcomes were observed in 3,140 reporting counties or combined county entities.

Key Independent Variables and Covariates

The primary independent variable in this study is the CDC/ATSVR 2018 SVI composite measure. The composite measure, which captures overall county-level social vulnerability, is calculated from 15 variables from the 2014-2018 American Community Survey, comprised of socioeconomic status (SES) (including poverty, unemployment, income, and education), household composition and disability (including the number of older adults and minors, people with disability, and single-parent households), racial/ethnic minority status and language (including racial/ethnic minorities and people who have difficulty speaking English), and housing type and transportation indicators (including multi-unit structures and group quarters, mobile homes, crowding, and lack of a personal vehicle).[29,30] We categorized the composite SVI measure into terciles (1 = lowest, 2 = mid, and 3 = highest tercile of vulnerability) as is commonplace.[15,19,31]

The second independent variable is mask mandates. We modeled this as a continuous variable measuring the proportion of time each county had a mask mandate enacted over the period beginning with the first mask mandate on April 15, 2020 to November 30, 2021 (i.e., for each county, the number of days spent under a mask mandate divided by the number of days of the longest mask mandate recorded in the dataset, 595 days, which is present in each SVI tercile), ranging from 0 to 1. We aggregated cumulative infection and mortality rates in counties

containing case and death counts prior to the first mask mandate to April 15, 2020, providing a common baseline date and time period spanning to the end of November from which to measure infection and mortality levels by the proportion of time spent under a mask mandate.

The third independent variable is an interaction term between SVI and mask mandates. The results of the tests of the interaction term yield two key pieces of information. First, they tell us whether the magnitudes of the associations of infection and mortality by the amount of time under mask mandates change across the upper two SVI terciles. The results of these tests address Aim 1. Second, the results of the interaction tests tell us whether the magnitudes of infection and mortality disparities between SVI terciles change as a function of time under mask mandates. The results of these tests address Aim 2.

Covariates include population density, as measured by population per housing units, since density has been cited as one of the most important predictors of COVID-19 spread.[19,32-35] Additionally, we incorporated intervention measures of social distancing, COVID-19 testing, and COVID-19 vaccination from the 2021 Pandemic Vulnerability Index (PVI) (a pandemic vulnerability score based on infection rates, population vulnerabilities, and COVID-19 interventions).[36] The social distancing measure is based on the Unacast Social Distancing Scoreboard Grade, a premier geolocation algorithm indicating the comparative level of distancing from mobility data collected through cell phones; the U.S. Department of Health and Human Services (HHS) COVID-19 testing indicator is a statewide cumulative measure of the proportion of tests per population; and the HHS COVID-19 vaccination variable, the percentage of vaccinated residents, is a cumulative measure of the proportion of vaccinations per population.[26,37] The range of each is from 0, representing the lowest score or proportion of social distancing, testing, and vaccinations, to 1, representing the

highest, as a collective set of measures of county-level implementation of COVID-19 infection control.[36,38,39]

Statistical Analysis

We calculated descriptive statistics in Stata 17.0, including means (and pairwise comparison tests of means with reference to the lowest tercile of SVI), standard deviations, medians, and the range (min and max values) of case and death counts per 100,000 population, days under a mask mandate, percent of days under a mask mandate, population density, social distancing, testing, and vaccinations. Because the infection and mortality data are counts of cases and deaths and are overdispersed, we conducted negative binomial regression analyses on both across the timeframe. For our first aim, we regressed case and death counts onto the interaction of composite SVI and mask mandates, controlling for population density, social distancing, testing, and vaccinations. In two separate analyses, we set the reference group as the mid tercile first and then the high SVI tercile second, to evaluate whether mask mandates for the full period are associated with decreases in COVID-19 infection and mortality in these two highest terciles of vulnerable communities, relative to infection and mortality with no mask mandates (i.e., mask mandates 0% of the time). For our second aim, we repeated the negative binomial regressions with the same model specification, but changed the SVI reference group to the low-vulnerability tercile. This allowed us to compare SVI disparities in infection and mortality relative to the lowest vulnerability communities, and to express associations between SVI terciles and mask mandates as reductions in infection and mortality disparities. To aid in interpretation of these results, we transformed the SVI, mask mandate, and interaction coefficients into incident rate

ratios (IRRs) and calculated 95% confidence intervals (CI) for these IRRs of COVID-19 cases and deaths. We also plotted linear trends of predicted case and death counts by terciles of SVI across mask mandate durations in two separate figures to illustrate these disparities and their reductions.

Results

Descriptive Statistics

Table 1 presents summary statistics of COVID-19 case and death counts per 100,000 in the county population by SVI tercile, and summary statistics by SVI tercile for days under a mask mandate, proportion of time under a mask mandate, population density, social distancing, testing, and vaccinations. Infection and mortality were highest among counties in the highest SVI tercile, with 17,261 cases and 362.1 deaths per 100,000 population, on average. Mid-SVI counties experienced an average of 15,896.9 cases and 282.4 deaths across the timeframe.

Table 1. Summary of Covid-19 Cases and Deaths by Social Vulnerability and Mask Mandates from January 21, 2020 to November 30, 2021

	Mean (SD)	Median	Min	Max
Cases per 100,000 Pop. by SVI				
Low (Least Vulnerable)	15211.3 (3,803.5)	15,468	1,134	29,612
Mid	15,896.9* (3,638.7)	16,001	5,761	57,771
High (Most Vulnerable)	17,261.0* (3,855.2)	17,082	5,082	43,251
Deaths per 100,000 Pop. by SVI				
Low (Least Vulnerable)	238.8 (137.7)	219	0	950
Mid	282.4* (120.4)	272	18	958
High (Most Vulnerable)	362.1* (139.6)	351	0	1103
Days Under a Mask Mandate by SVI				
Low (Least Vulnerable)	244.7 (165.8)	273	0	595
Mid	256.8 (182.9)	273	0	595
High (Most Vulnerable)	219.9* (177.4)	251	0	595
Proportion of Time Under a Mask Mandate by SVI				
Low (Least Vulnerable)	0.41 (0.28)	0.45	0	1
Mid	0.43 (0.31)	0.46	0	1
High (Most Vulnerable)	0.37* (0.30)	0.42	0	1
Population Density by SVI				
Low (Least Vulnerable)	2.08 (0.47)	2.09	0.55	3.85
Mid	2.14* (0.41)	2.15	0.49	3.69
High (Most Vulnerable)	2.19* (0.38)	2.17	0.64	3.87
Social Distancing by SVI				
Low (Least Vulnerable)	0.79 (0.27)	1	0	1
Mid	0.85* (0.23)	1	0.10	1
High (Most Vulnerable)	0.84* (0.23)	1	0.10	1
COVID-19 Testing by SVI				
Low (Least Vulnerable)	0.67 (0.13)	0.69	0.10	1
Mid	0.66* (0.12)	0.67	0.14	1
High (Most Vulnerable)	0.61* (0.13)	0.62	0	1
COVID-19 Vaccinations by SVI				
Low (Least Vulnerable)	0.53 (0.14)	0.53	0	0.95
Mid	0.49* (0.12)	0.48	0.13	1
High (Most Vulnerable)	0.46* (0.13)	0.46	0.08	1

* denotes statistically significant differences in means between upper terciles and lowest tercile (reference) of SVI at $p < 0.05$. † SVI denotes Social Vulnerability Index.

The average length and proportion of time spent under a mask mandate was lowest among high SVI counties at nearly 220 days or 37% of the time, and highest, although not statistically significant, in mid SVI counties at 257 days or 43% of the time, with a minimum of no days and a maximum of 595 days. Average population density was highest among high SVI counties at 2.19 individuals per household, and lowest among low SVI counties at 2.08. Social distancing scores were the greatest among mid and high SVI counties at 0.85 and 0.84, respectively, compared to low SVI counties at 0.79, indicating relatively high levels of social distancing in each tercile of vulnerability. Testing was the lowest in high SVI counties at .61, compared to low and mid SVI counties at 0.67 and 0.66, respectively, showing mid to high levels of testing overall. Vaccinations was the greatest in low SVI counties at 0.53, followed by mid SVI at 0.49 and high SVI at .46, demonstrating moderate levels of vaccination, across all U.S. counties.

Aim 1 Analytic Results

Figure 1 presents IRRs for COVID-19 cases and deaths in mid and high-SVI counties under mask mandates for the full time timeframe (100% of the time) compared to mid and high-SVI counties with no mask mandates (0% of the time). Mask mandates were associated with significant decreases in both infection and mortality among the most vulnerable communities. Cases were 11% and 21% lower in high-SVI and mid-SVI counties, respectively, with mandates in place for the entire period compared to high-SVI and mid-SVI counties with no mask mandates (Cases IRR: 0.89; 95% CI, 0.85-0.94; Cases IRR: 0.79; 95% CI, 0.75-0.83). Additionally, deaths were 12% and 10% lower in high-SVI and mid-SVI counties, respectively,

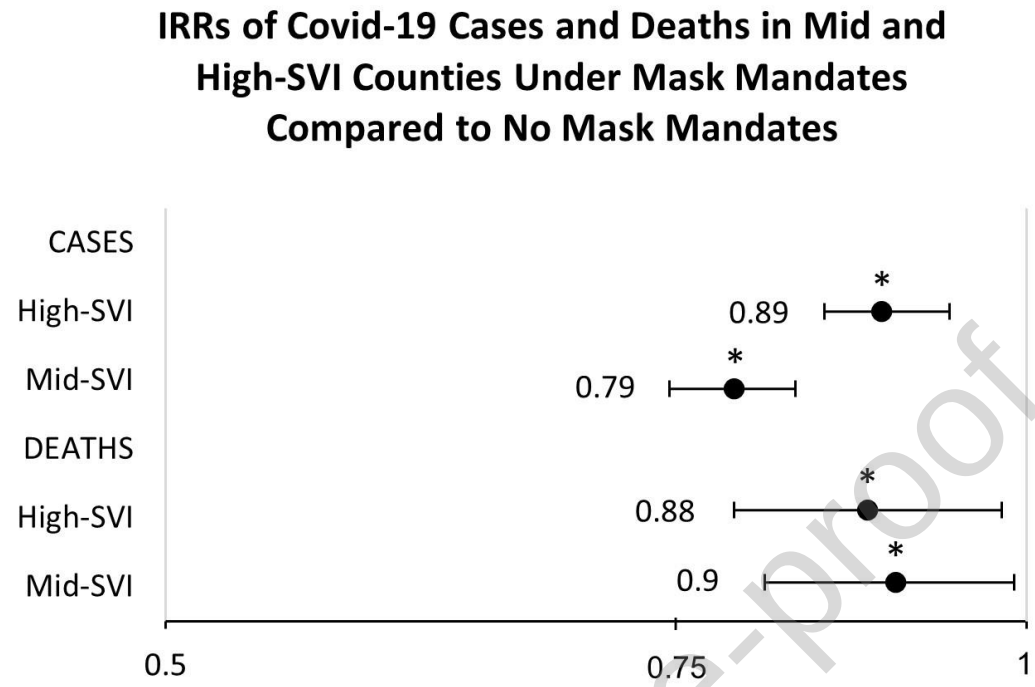

Figure 1. IRRs of Covid-19 Cases and Deaths per 100,000 in High and Mid SVI Counties under Mask Mandates for the Full Period (100% of Time) Compared to High and Mid SVI Counties with No Mask Mandates (0% of Time). * denotes statistically significant associations at $p < 0.05$. † Incident Rate Ratios **(**IRRs) represent the percent change in cases and deaths in mid/high-SVI counties associated with mask mandates for the full timeframe of 595 days compared to mid/high-SVI counties with no mask mandates. ‡ Fully adjusted models include interactions of composite SVI and mask mandates, with high and mid terciles of SVI as the references, controlling for population density, social distancing, testing, and vaccinations.

with mandates in place for the entire period compared to high-SVI and mid-SVI counties with no mask mandates (Deaths IRR: 0.88; 95% CI, 0.79-0.98; Deaths IRR: 0.90; 95% CI, 0.81-0.99).

Aim 2 Analytic Results

Table 2 shows results of tests of the presence of infection and mortality disparities in mid and high-SVI terciles compared to the low-SVI tercile, and tests of the mitigation of these disparities by mask mandates. We found evidence of changes in the magnitudes of the high/low-SVI

Table 2. IRRs of Covid-19 Cases and Deaths by SVI with and without Mask Mandates

		IRRs of Cases/Deaths per 100,000 Pop. by SVI (95% CI)		
		Low	**Mid**	**High**
Cases	No Mandate	1.00 (Ref.)	1.08 (1.05 to 1.12)*	1.10 (1.06 to 1.14)*
	Mandate for Full Period	1.00 (Ref.)	0.99 (0.95 to 1.04)	1.14 (1.09 to 1.20)*
	Change in IRR		0.92 (0.85 to 0.98)*	1.04 (0.96 to 1.11)
Deaths	No Mandate	1.00 (Ref.)	1.25 (1.16 to 1.34)*	1.57 (1.46 to 1.69)*
	Mandate for Full Period	1.00 (Ref.)	1.06 (0.97 to 1.17)	1.32 (1.19 to 1.45)*
	Change in IRR		0.85 (0.74 to 0.99)*	0.84 (0.72 to 0.97)*

* denotes statistically significant associations at $p < 0.05$. † IRRs denote Incident Rate Ratios. ‡ No Mandate (0% of Time) IRRs represent the percent change in cases and deaths in mid and high-SVI counties associated with no mask mandates compared to low-SVI counties with no mask mandates. Mandate for Full Period (100% of Time) IRRs represent the percent change in cases and deaths in mid and high-SVI counties associated with full-timeframe mask mandates compared to low-SVI counties with full-timeframe mask mandates. Change in IRR coefficients represent the percent change in the magnitude of No Mask Mandate and Mandate for Full Period IRRs in mid and high-SVI counties with reference to low-SVI counties. § Fully adjusted models include interactions of composite SVI and mask mandates, with the lowest tercile of SVI as the reference, controlling for population density, social distancing, testing, and vaccinations, the coefficients of which can be found in Tables 3 and 4 in the Appendix.

mortality disparities associated with longer mask mandates, and changes in the magnitudes of the mid/low-SVI infection and mortality disparities associated with mask mandate durations.

The strongest evidence of the mitigating associations of mask mandates was found in mortality disparities between high and low-SVI counties. COVID-19 mortality in high-SVI counties with no mask mandates was 1.57 times higher than in low-SVI counties with no mask mandates. Mortality was 1.32 times higher in high-SVI counties with full-period mask mandates than in low-SVI counties with full-period mask mandates, indicating a 16% reduction in the magnitude of the high/low-SVI disparity (Change in IRR: 0.84; 95% CI, 0.720.97, Table 2). Other evidence of these mitigating associations was found between mid and low-SVI counties in mortality, with a 15% reduction in the magnitude of the mid/low-SVI disparity

Table 3. Negative Binomial Regression of COVID-19 Cases and Deaths per 100,000 Population by Interaction of SVI and Mask Mandates

Cases	IRR		95% CI
SVI (Ref. Low-SVI)			
Mid	1.08	***	1.05-1.12
High	1.10	***	1.06-1.14
Mask Mandates (Low-SVI)	0.86	***	0.79-0.89
SVI X Mask Mandates (Ref. Low-SVI)			
Mid	0.92	*	0.85-0.98
High	1.04		0.96-1.11
Population Density	1.07	***	1.04-1.09
Social Distancing	0.92	***	0.89-0.96
COVID-19 Testing	1.07		0.99-1.15
COVID-19 Vaccinations	0.83	***	0.77-0.89
Deaths			
SVI (Ref. Low-SVI)			
Mid	1.25	***	1.16-1.34
High	1.57	***	1.46-1.69
Mask Mandates (Low-SVI)	1.04		0.93-1.21
SVI X Mask Mandates (Ref. Low_SVI)			
Mid	0.85	*	0.74-0.99
High	0.84	*	0.72-0.97
Population Density	0.86	***	0.82-0.90
Social Distancing	0.87	***	0.81-0.95
COVID-19 Testing	0.80	**	0.68-0.95
COVID-19 Vaccinations	0.43	***	0.37-0.50

* = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$ † SVI denotes Social Vulnerability Index. ‡ IRRs denote Incident Rate Ratios. § SVI IRRs represent the percent difference in cases and deaths between Mid and High-SVI counties with no mask mandates and Low-SVI counties with no mask mandates. Mask Mandate IRRs represent the percent difference in cases and deaths in Low-SVI counties, the reference, associated with full-timeframe mask mandates compared to Low-SVI counties with no mask mandates. SVI X Mask Mandates IRRs represent the percent change in the magnitude of living under no mask mandates (or the SVI IRRs as shown above) compared to living under a full-timeframe mask mandate (or Mandate for Full Period IRRs as shown in Table 2) in mid and high-SVI counties with reference to low-SVI counties. ‖ Fully adjusted models include interactions of composite SVI and mask mandates, with the lowest tercile of SVI as the reference, controlling for population density, social distancing, testing, and vaccinations.

(Change in IRR: 0.85, 95% CI, 0.74-0.99, Table 2), as well as infection disparities between mid and low-SVI counties with an 8% reduction in magnitude (Change in IRR: 0.92, 95% CI, 0.85-0.98, Table 2).

Table 3 shows the full factorial output from the tests of the presence of infection and mortality disparities in mid and high-SVI terciles compared to the low-SVI tercile, and tests of the mitigation of these disparities by mask mandates; these models include tests of the association of population density, social distancing, testing, and vaccination controls with infection and mortality. Greater population density was associated with higher infection (IRR: 1.07; 95% CI, 1.05-1.09) but lower mortality (IRR: 0.86; 95% CI, 0.82-0.90), while social distancing and vaccinations were associated with both lower infection (IRR: 0.92; 95% CI, 0.89-0.96; IRR: 0.83; 95% CI, 0.77-0.89, respectively) and mortality (IRR: 0.87; 95% CI, 0.81-0.95; IRR: 0.43; 95% CI, 0.37-0.50, respectively). Testing was associated only with lower mortality (IRR: 0.80; 95% CI, 0.68-0.95).

Figure 2 illustrates the change in the magnitude in infection disparity mitigation across longer durations of mask mandates. In Figure 2, the mid-SVI line sits above the low-SVI line, indicating greater infection in mid-SVI counties as the time spent under a mask mandate increases from 0 to 595 days or 0% to 100% of the time period (corresponding to the Figure 1 Cases IRR of 0.79), and a less dramatic reduction in predicted cases for low-SVI counties, such that the difference between the lines narrows with growing durations of mask mandates. This is in contrast to high-SVI counties, which experienced a similar change in the number of cases as low-SVI counties across increasing durations of mask mandates, the trends of which are more or less parallel.

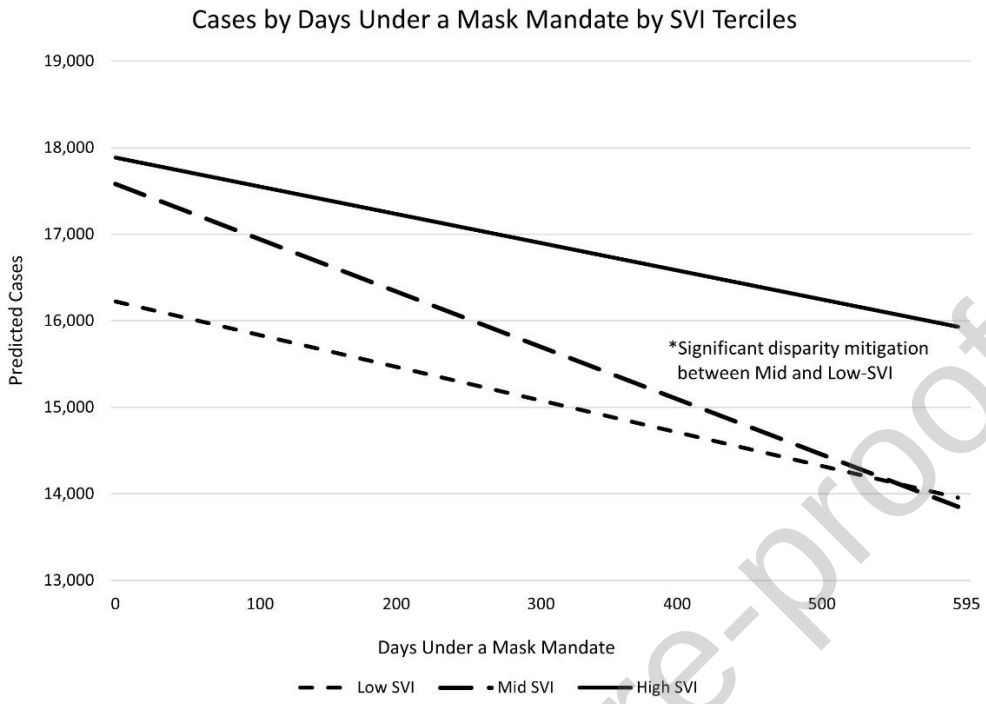

Figure 2. Predicted Cases per 100,000 by Increasing Duration of Mask Mandates by Terciles of SVI. * Fully adjusted model includes interaction of composite SVI and mask mandates, with the lowest tercile of SVI as the reference, controlling for population density, social distancing, testing, and vaccinations.

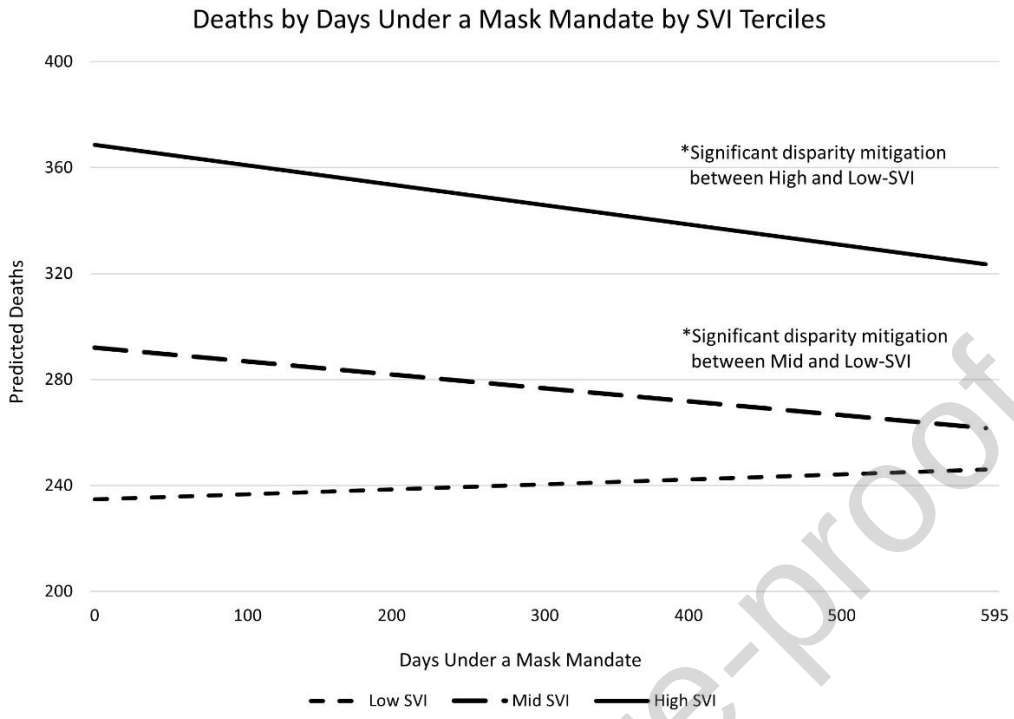

Figure 3. Predicted Deaths per 100,000 by Increasing Duration of Mask Mandates by Terciles of SVI. * Fully adjusted model includes interaction of composite SVI and mask mandates, with the lowest tercile of SVI as the reference, controlling for population density, social distancing, testing, and vaccinations.

However, Figure 3 demonstrates disparity mitigation in mortality across increasing durations of mask mandates between both mid and high-SVI trends lines with reference to low-SVI counties. As the duration of mask mandates increased, mortality decreased in mid and high-SVI counties (corresponding to Figure 1 Deaths IRRs of 0.9 and 0.88, respectively), and in fact, the trends of both converge upon the low-SVI line, representing significant disparity mitigations for each.

Discussion

Our study examined the associations of mask mandates with COVID-19 infection and mortality in socially vulnerable communities and whether these mandates were associated with mitigation

of disparities in these communities during the pandemic. We found that in the most vulnerable counties, mask mandates were associated with a decrease in cases and deaths. We also found that mask mandates were associated with a narrowing of infection disparities between low and mid terciles of vulnerability as well as narrowing of mortality disparities among mid and high terciles of vulnerability compared to the lowest tercile.

Our findings corroborate and expand upon a growing literature, which demonstrates that higher levels of social vulnerability are associated with increased COVID-19 infection and mortality.[4,5] To our knowledge, only one study has looked at mask policies and COVID-19 mortality among the most socially vulnerable of counties, and it found a benefit.[18,19,23] Our findings of the association between increasing duration of mask mandates and decreases in COVID-19 infection and mortality in mid and high-SVI counties were an extension of their findings in that we controlled in our study not only for testing and social distancing but vaccinations as well. In addition, our findings reflect that benefits accrued to vulnerable communities with increasing time under mask mandates, even if these mandates were not enacted for the entire timeframe.

Furthermore, however, our finding that disparities between high and low-SVI counties were smaller when mask mandates were enacted for the entire timeframe makes an important contribution to the disparities literature. In both the infection and mortality analyses, the widest disparities in social vulnerability took place in counties with no implementation of mask mandates, compared to those with mandates in place for the full timeframe showing insignificant differences in case and death counts between low and mid-SVI counties. These results suggest a mitigation of disparities above and beyond other infection control measures favorable to the most vulnerable of communities.

However, one of the challenges of examining the long-term associations of mask mandates on COVID-19 outcomes is the difficulty in demonstrating causality, because mask mandates were often implemented or rescinded, and sometimes implemented again in response to changes in COVID-19 infection rates, and implemented at different times and locations, making it difficult to find appropriate comparison groups across time and space. Understanding the shorter-term effects of mask mandates has been demonstrated in the literature, but longer-term analyses are scarce and can be fraught with challenges such as multiple and discontinuous treatment periods and treatment assignments that do not measure meaningful differences in mandate durations or are poorly matched. [40,41] To understand the face-value relationship between COVID-19 infection and mortality and vulnerability and any mitigation of disparities through the total amount of time spent under mask mandates, we modeled cases and deaths through an interaction of SVI and percentage of time spent under a mandates over a large cross section of nearly two years. In doing so, we discovered significant relationships between COVID-19 outcomes and SVI terciles across increasing durations of mask mandates as trends of decline. Our analytic approach and timeframe accounted for recurrent infection and mortality surges that may not have overlapped cleanly with off-and-on mask mandate durations. Thus, our study which found correlations between mask mandates and lower COVID-19 infection and mortality, along with a narrowing of disparities, is an important exploratory analysis suggesting potential relationships that can be further explored through causal methods.

A limitation of our study is that we modeled mask mandates instead of mandate adherence. Our findings suggest that the most vulnerable communities appear to benefit most from mask mandates, but one possible explanation for these findings is that individuals in high-SVI counties may be more likely to mask, irrespective of mandates, whereas individuals in low-

SVI counties may adopt masking behaviors with mandates. Indeed, limited evidence has suggested that mask-wearing is more common among lower income groups, and that regulations alone may not be driving increases in masking behavior.[42] An additional limitation is that the COVID-19 Omicron variant, which was first detected in the United States in late 2021 and has accounted for many more cases than any other period during the pandemic, was not analyzed in this study as part of our timeframe. Finally, this study does not measure masking behavior in the absence of mandates, neither does it account for advances in therapeutics, healthcare access, healthcare quality, health status, or comorbidity. However, our study had several strengths: We considered associations over a lengthy timeframe, and specifically examined associations between COVID-19 outcomes and mask mandates in and between different levels of community vulnerability, augmenting the limited, but needed, research on this topic. Few studies have investigated the relationship between COVID-19 infection and mask mandates over a larger period of time, and even less have attempted to do so in and between different levels of community vulnerability.[19]

Conclusion

Our study suggests that longer durations of mask mandates were related to reductions in excess infection and mortality and in mitigating infection and mortality disparities in the most vulnerable communities. Furthermore, disparities between high and low social vulnerability communities narrowed in communities with mask mandates. Ongoing and future disaster planning and infection control efforts should consider examining the supports necessary to maintain benefits of public health policies for as long as needed in vulnerable communities.

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Highlights

- Longer mask mandate durations are associated with decreases in COVID-19 infection and mortality.
- Between levels of social vulnerability, these associated reductions are most pronounced among higher levels of vulnerability.
- Mask mandates are also associated with mitigations of COVID-19 infection and mortality disparities between higher and low levels of social vulnerability.