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The Association Between State-Issued Mask Mandates and County COVID-19 Hospitalization Rates

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ABSTRACT

Context: Mask mandates are one form of nonpharmaceutical intervention that has been utilized to combat the spread of SARS-CoV2, the virus that causes COVID-19.

Objective: This study examines the association between state-issued mask mandates and changes in county-level and hospital referral region (HRR)–level COVID-19 hospitalizations across the United States.

Design: Difference-in-difference and event study models were estimated to examine the association between state-issued mask mandates and COVID-19 hospitalization outcomes.

Participants: All analyses were conducted with US county-level data.

Interventions: State-issued mask mandates. County-level data on the mandates were collected from executive orders identified on state government Web sites from April 1, 2020, to December 31, 2020.

Main Outcome Measures: Daily county-level (and HRR-level) estimates of inpatient beds occupied by patients with confirmed or suspected COVID-19 were collected by the US Department of Health and Human Services.

Results: The state issuing of mask mandates was associated with an average of 3.6 fewer daily COVID-19 hospitalizations per 100 000 people ($P < .05$) and a 1.2-percentage-point decrease in the percentage of county beds occupied with COVID-19 patients ($P < .05$) within 70 days of taking effect. Event study results suggest that this association increased the longer mask mandates were in effect. In addition, the results were robust to analyses conducted at the HRR level.

Conclusions: This study demonstrated that state-issued mask mandates were associated with reduction in COVID-19 hospitalizations across the United States during the earlier portion of the pandemic. As new variants of the virus cause spikes in COVID-19 cases, reimposing mask mandates in indoor and congested public areas, as part of a layered approach to community mitigation, may reduce the spread of COVID-19 and lessen the burden on our health care system.

KEY WORDS: COVID-19, hospitalization, mask mandates

In the spring of 2020, the US Centers for Disease Control and Prevention (CDC) recommended a combination of evidence-based strategies to decrease the transmission of SARS-CoV-2, the virus that causes coronavirus disease 2019 (COVID-19).[1,2] Given that the virus is predominantly spread by inhaling aerosol droplets and/or aerosol particles from infected individuals,[3] one such policy was universal mask-wearing. Since April 11, 2020, many state

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governments have issued mask mandates to slow the spread of SARS-CoV-2, and by the end of 2020, 38 states and the District of Columbia issued requirements that individuals wear masks when in public settings.[4]

In addition to the serious health concerns of contracting COVID-19, the pandemic has caused capacity issues in hospitals across the United States.[5,6] Intensive care units (ICUs) have had to balance admission of patients with COVID-19 with non–COVID-19 patients, resulting in situations where no space is available for patients who need intensive care.[7] This may be one reason for an uptick in mortality resulting from other prevalent diseases since the start of the pandemic.[8] While capacity issues persist, hospital staff are also strained from the continued stress of working on the front lines of the pandemic, resulting in high rates of turnover in critical hospital staff positions.[6]

State-issued mask mandates have been associated with decreases in COVID-19 case and death growth rates[4,9]; however, less is known regarding the association between state-issued mask mandates and hospitalization rates. It follows that this documented reduction in COVID-19 incidence may also lead to reductions in COVID-19 hospitalizations. In addition, the effect of mask mandates on hospitalizations may be larger than their effect on overall incidence if more vulnerable populations are the ones most protected via masking. To our knowledge, only a few studies have examined the association between mask mandates and COVID-19 hospitalizations, finding that state-issued mask mandates were associated with a decrease in COVID-19 hospitalization growth rates[10-12]; however, these studies were limited in scope (limited geography) and/or in hospitalization outcomes examined.

The goal of this study was to expand upon this previous work, estimating both a difference-in-difference (DID) and event study model using newly available county-level hospitalization data to examine the association between state-issued mask mandates and county-level estimates of inpatient beds occupied by a patient with confirmed or suspected COVID-19 in the United States. These quasi-experimental approaches leverage the temporal and geographic variations in state-issued mask mandate implementation to identify this association and are widely used approaches when evaluating the health impacts of policy implementation.

In addition, this study examined the association between mask mandates and the proportion of inpatient beds occupied by a patient with confirmed or suspected COVID-19 (among all available inpatient beds) and explored the robustness of these findings when examining the association at the hospital referral region (HRR), a geographic level synonymous with hospital commuting patterns. Within the context of nonpharmaceutical interventions (NPIs) and COVID-19 hospitalizations, this study is the first to examine associations at the HRR level, providing an alternative approach through which to study the impact of state-issued mask mandates. The results of this study can help inform policy makers who may be considering reissuing mask mandates in the future.

Methods

Study sample and measures

County-specific data on state-issued mask mandates, gathering bans, stay-at-home orders, and restaurant and bar closures were obtained from executive and administrative orders identified on state government Web sites from April 1, 2020, to December 31, 2020.[13] These community-level prevention policies were analyzed and coded to extract prevention strategy variables, their effective dates and expiration dates, and the counties to which the state-issued orders applied when state-issued measures varied by county.[4] State-issued mask mandates were defined as requirements for persons to wear a mask either (1) anywhere outside their home or (2) in both retail businesses and in restaurants. State-issued restrictions on restaurants or bars were defined as prohibitions on restaurants or bars operating or limiting service to takeout, curbside pickup, or delivery. State-issued stay-at-home orders were defined as requirements for all individuals to stay at home or shelter in their place of residence. State-issued gathering bans were defined as prohibitions on the gathering of any number of people. All data underwent secondary review and quality assurance checks. April 1, 2020, to December 31, 2020, was chosen as the sample period primarily due to 2 factors: (1) the majority of state-issued mask mandates were implemented over this period; and (2) this time frame predates COVID-19 vaccine rollouts to the general population, which may confound our ability to analyze the association between state-issued mask mandates and COVID-19 hospitalizations.

Daily county-level estimates of inpatient beds occupied by a patient with confirmed or suspected COVID-19 were estimated using small area estimation based on a daily, combined, cleaned, hospital-level combination of available COVID-19 hospitalization data collected by the US Department of Health and Human Services Unified Hospital Data Surveillance System and augmented by data held by CDC's National Healthcare Safety Network (NHSN). Daily, facility-level data were matched to the list of acute care hospitals required to report health care–associated infection data to NHSN and de-duplicated.

Cleaning was applied to remove erroneous values using sigma checks and by comparison with neighboring points in the time series using a running histogram approach. For each day, values in the surrounding 61-day period were placed into bins with a width of one-tenth of the median (with a minimum bin width of 3). Clusters of bins with 4 or fewer observations that were 3 or more bin widths from other values were removed. Additional cleaning was required for the reported daily total number of staffed inpatient beds, which had been inconsistently reported, leading to some facilities having erroneous large jumps or dips that were inconsistent with reported admissions. The histogram approach was used to cluster bins, and in facilities with multiple clusters, those clusters 50% lower or higher than the number of inpatient beds reported to the NHSN annual patient safety survey were removed and filled with forward imputation. Small area estimation[14] was applied using a negative binomial generalized linear mixed model with total inpatient beds as a log offset in the model. This model was used to produce empirical Bayes estimates of daily reported inpatient beds occupied by a patient with confirmed or suspected COVID-19 for each county. Small area estimates were produced using SAS version 9.4.

The dependent variables used in the analysis are as follows: (1) daily number of inpatient beds occupied by a patient with confirmed or suspected COVID-19 per 100 000 people (ie, daily COVID-19 hospitalization rate); and (2) daily number of inpatient beds occupied by patients with confirmed or suspected COVID-19 expressed as a percentage of all staffed inpatient beds. The referenced county for both variables was based on the location of the inpatient bed and not the patient's county of residence. The final sample used for analysis included 2450 counties, representing 78% of US counties. Counties that had no acute care hospitals were excluded from the analysis.

Statistical analysis

The association between state-issued mask mandates and the outcomes of interest was measured using a DID model.[15] The DID model has been widely used to examine the impact of implementing COVID-19 NPIs.[16-18] For the purposes of this study, the DID model utilizes temporal and geographic variations in the effective dates of state-issued mask mandates across US counties to identify their association with changes in COVID-19 hospitalization rates and hospital capacity. The model included a dummy variable indicating whether the county was subject to a state-issued mask mandate on a given day, 2-way fixed effects (daily and county), and controls for the presence or absence of other state-issued NPIs (ie, gathering bans, stay-at-home orders, restrictions on restaurants, and restrictions on bars).

To examine whether the impact of mask mandates on COVID-19 hospitalizations varied over time, we estimated an event study model (an advanced version of a controlled interrupted time series), a methodology commonly used to analyze policy impacts over time in public health.[4,9,10] For each county that was subject to a state-issued mask mandate, a reference period (0-14 days before mask mandate implementation) was compared with 7 mutually exclusive time ranges relative to the date the mask mandate took effect. The association was examined over 2 pre–mask mandate periods (42-29 and 28-15 days before the implementation of mask mandates) and 5 post–mask mandate periods (0-14, 15-28, 29-42, 43-56, and 57-70 days after the implementation of mask mandates). Observations from April 1, 2020, to December 31, 2020, for counties in states that did not issue a mask mandate were included in the analysis as a reference and were coded as zero for all the time range variables. A weighted least-squares regression with the 7 mutually exclusive time variables relative to the date the state-issued mask mandate took effect in each county, dummy variables that controlled for the presence or absence of other state-issued community prevention policies (ie, gathering bans, stay-at-home orders, restaurant closures, and bar closures), and county and day fixed effects was used to estimate the event study models.

Sensitivity analyses were estimated using models that rolled up the county data to approximately the level of the Dartmouth HRRs. The HRRs were created to represent contiguous areas of referral. HRRs are allowed to cross county boundaries, which makes aggregation challenging; thus, we aggregated county data to an approximation of the HRR, with each county allocated uniquely to a single HRR by the largest county population. These models help overcome a potential limitation of the analysis, and prior literature, as the hospital data are based on the location of the hospital and not the patient. Individuals may be hospitalized in counties different from their residence, which could lead to measurement error as the mask mandate status may differ between an individual's county of residence and the county in which he or she is hospitalized. The trade-off with this analysis is that while the geographic area better aligns with hospital commuting patterns, HRRs can cross state borders. This leads to some cases where counties in an HRR were subject to a state-issued mask mandate while others were not. To account for this, if an HRR included multiple states, counties within a given state were removed if they accounted for less than 20%

of the total HRR population. An HRR was then defined as subject to any particular NPI on any given day if at least one county within the HRR had an NPI in place.

Following recently published public health policy analyses, we tested the validity of the DID and event study research design by examining the coefficient estimates on the pre–mask mandate period variables of the event study model.[4,16,19] Coefficient estimates of zero for these variables would demonstrate that there were no differences in hospitalization trends between counties with and without state-issued mask mandates prior to the effective date of mask mandates, supporting the validity of the DID and event study research design.

All analyses were weighted by county population (HRR population for the sensitivity analysis) and estimated with robust standard errors clustered at the county level (HRR level for the sensitivity analysis). *P* values less than .05 were deemed statistically significant. Analyses were performed using Stata software (version 16.0; StataCorp LLC, College Station, Texas). The formal presentations of the models are provided in the Supplemental Digital Content Technical Appendix (available at http://links.lww.com/JPHMP/B29). This activity was reviewed by CDC and was conducted consistent with applicable federal law and CDC policy.*

Results

Within our sample, 73% of counties were subject to a state-issued mask mandate at some point during the study period, with a varied distribution of effective dates (Figure 1). The median date a county was first subject to a state-issued mask mandate in our sample was July 3, 2020. All results reported in the following text were statistically significant ($P < .05$).

The DID results suggest that state-issued mask mandates were associated with an average of 3.6 fewer daily COVID-19 hospitalizations per 100 000 people and a 1.2-percentage-point decrease in the percentage of county beds occupied with COVID-19 patients within 70 days of taking effect (Table). Stratified by time to effect, the event study results suggest that the state-issued mask mandates were associated with an average of 3.4, 7.2, 10.4, and 12.9 fewer daily county-level COVID-19 hospitalizations per 100 000 people and a 1.1-, 2.5-, 3.6-, and 4.6-percentage-point decrease in the percentage of beds occupied with COVID-19 patients 15-28, 29-42, 43-56, and 57-70 days after the mandates took effect, respectively, compared with the reference period (ie, 1-14 days before the mask mandates) (Figure 2; see Supplemental Digital Content Table 1, available at http://links.lww.com/JPHMP/B27).

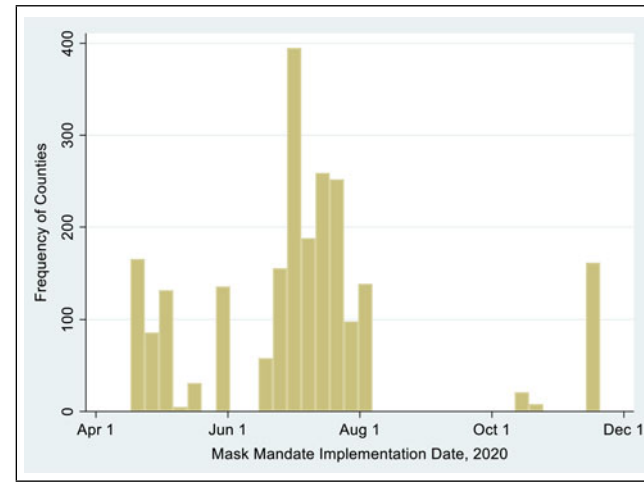

FIGURE 1 Frequency of Dates in Which Counties Were First Subject to a State-Issued Mask Mandate, April 1, 2020, to December 31, 2020[a]
[a]Policy data were collected from state government Web sites containing executive or administrative orders. State-issued mask mandates were defined as requirements for persons to wear a mask either (1) anywhere outside their home or (2) in both retail businesses and in restaurants/food establishments. This figure is available in color online (www.JPHMP.com).

Furthermore, the event study model results were robust to analyses conducted at the HRR level (Figure 3; see Supplemental Digital Content Table 2, available at http://links.lww.com/JPHMP/B28). These results suggest that state-issued mask mandates were associated with an average of 2.9, 6.8, 9.7, and 11.4 fewer daily HRR-level COVID-19 hospitalizations per 100 000 people and a 2.3-, 3.5-, and 4.4-percentage-point decrease in the percentage of HRR inpatient beds occupied with COVID-19 patients 29-42, 43-56, and 57-70 days after the mandates took effect, respectively, compared with the reference period (ie, 1-14 days before the mask mandates).

Across most specifications of the event study model, the pre–mask mandate time variables were statistically different from the reference period. This suggests that the parallel trend assumption of the model referenced earlier may not be satisfied. In other words, there may have been other unobserved factors correlated with county COVID-19 hospitalizations that may have contributed to the timing of state-issued mask mandates.

Discussion

The results of this study suggest that state-issued mask mandates were associated with a significant

*See, for example, 45 CFR part 46, 21 CFR part 56; 42 USC §241(d); 5 USC §552a; 44 USC §3501 *et seq*.

TABLE

The Association Between State-Issued Mask Mandates and County-Level Changes in Numbers of COVID-19 Hospitalizations per 100 000 People and Percentage of Beds Occupied With COVID-19 Patients, April 1, 2020, to December 31, 2020: Difference-in-Difference Results[a]

	COVID-19 Hospitalizations per 100 000 People	Percent of Beds Occupied With COVID-19 Patients
Mask mandate variable	**−3.6 (−5.9, −1.2)**	**−1.2 (−2.0, −0.3)**

[a] *Policy data were collected from state government Web sites containing executive or administrative orders. County hospitalization data were collected by the Department of Health and Human Services. All models controlled for other state-issued community prevention policies (ie, stay-at-home orders, gathering bans, restaurant closures, and bar closures) and included county and day fixed effects. Results are displayed as coefficient estimates, and 95% confidence intervals are reported in parentheses.* **Bolded** *estimates indicate* $P < .05$. *All analyses were weighted by county population and estimated with robust standard errors clustered at the county level.*

decrease in the number of county hospital inpatient beds occupied by patients with COVID-19 in the counties for which the policies were applied within 70 days of taking effect. To put our findings into context, the DID results suggest that mask mandates were associated with 9071 hospitalizations averted in the 70 days after mandates took effect among states that issued mask mandates.

In addition to the health benefits of averted COVID-19 hospitalizations, the results of this analysis are important in the context of the health care sector. Our finding that state-issued mask mandates were associated with reductions in the percentage of hospital beds occupied by a patient with confirmed or suspected COVID-19 suggests that mask mandates may have helped reduce the burden of COVID-19 on the health

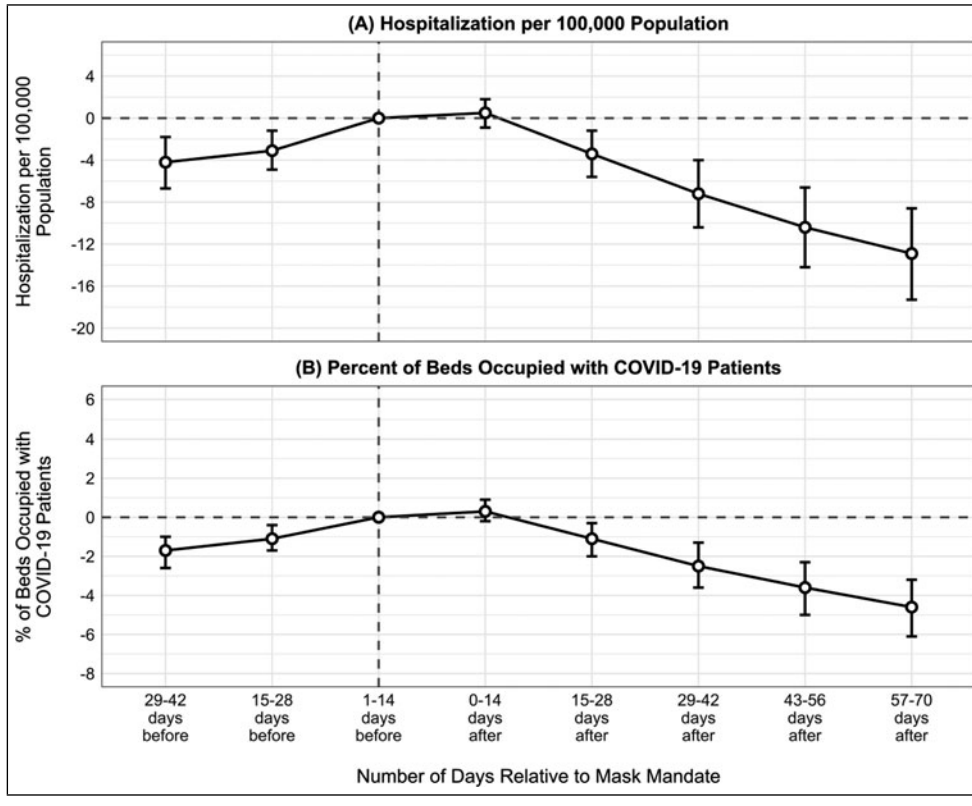

FIGURE 2 The Association Between State-Issued Mask Mandates and County-Level Changes in Numbers of COVID-19 Hospitalizations per 100 000 People and Percentage of Beds Occupied With COVID-19 Patients, April 1, 2020, to December 31, 2020: Event Studies Results[a]

[a] Policy data were collected from state government Web sites containing executive or administrative orders. County hospitalization data were collected by the Department of Health and Human Services. All models controlled for other state-issued community prevention policies (ie, stay-at-home orders, gathering bans, restaurant closures, and bar closures) and included county and day fixed effects. Results are displayed as coefficient estimates and 95% confidence intervals. All analyses were weighted by county population and estimated with robust standard errors clustered at the county level.

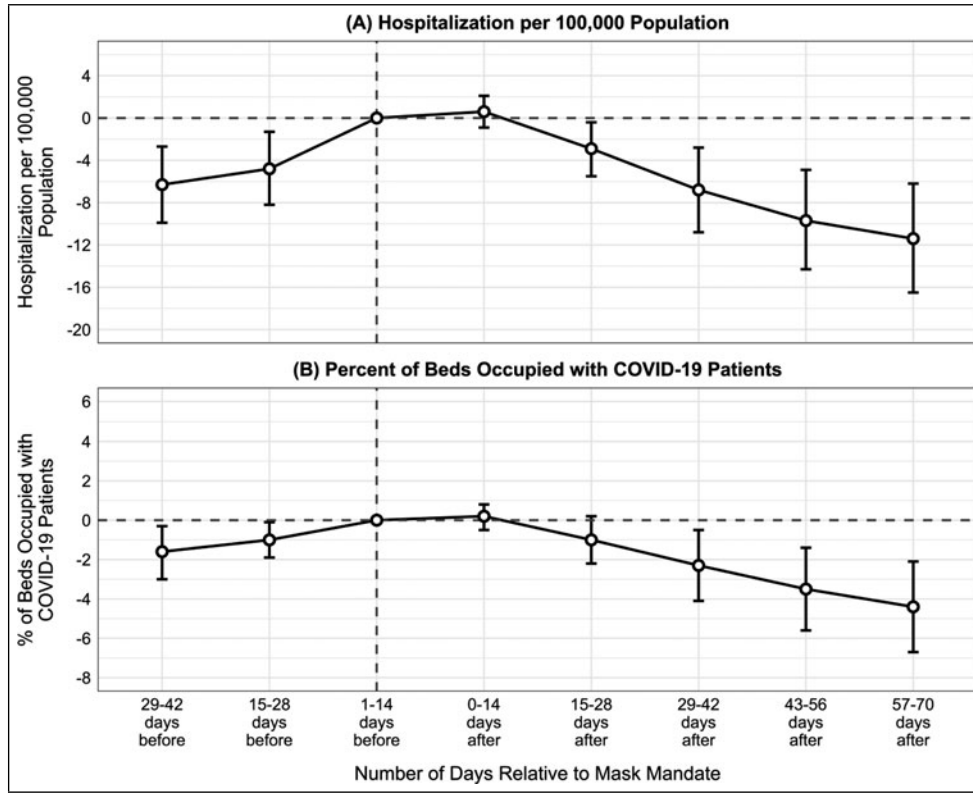

FIGURE 3 The Association Between State-Issued Mask Mandates and HRR-Level Changes in Numbers of COVID-19 Hospitalizations per 100 000 People and Percentage of Beds Occupied With COVID-19 Patients, April 1, 2020, to December 31, 2020: Event Studies Results[a]
Abbreviation: HRR, hospital referral region.
[a]Policy data were collected from state government Web sites containing executive or administrative orders. HRR hospitalization data were collected by the Department of Health and Human Services. All models controlled for other state-issued community prevention policies (ie, stay-at-home orders, gathering bans, restaurant closures, and bar closures) and included HRR and day fixed effects. Results are displayed as coefficient estimates and 95% confidence intervals. All analyses were weighted by HRR population and estimated with robust standard errors clustered at the county level.

care sector through averted COVID-19 hospitalizations. This is particularly important as it suggests that mask mandates may have helped "flatten the curve," allowing ICUs to care for both patients diagnosed with COVID-19 and patients with other serious diagnoses. The reduction in COVID-19 admissions may also have dampened the economic burden of the pandemic to insurers and patients by preventing costly hospitalizations.[20-22]

Our finding that shows COVID-19 hospitalizations and the percentage of beds occupied decreased over time after mask mandates were issued is consistent with prior literature[9] and suggests that these policies were more effective once individuals had time to adjust their behavior and social norms developed.[23] In fact, recent literature suggests that mask-wearing norms may have even persisted after states began lifting mask mandate orders in 2021.[12] In addition, reductions in secondary transmissions after mask mandates may be another explanation for this decrease over time.

Furthermore, this study is the first to examine these associations at the HRR level, which provide a more accurate correlation between the patients' residency and hospital location. Previous literature finding an association between mask mandate implementation and reductions in COVID-19 hospitalizations when constrained to analyses at the state and county levels is further validated by these findings.[10-12]

This study is subject to several limitations. First, regardless of the geographic level used for analysis, shortcomings persist. As county-level analysis leads to discrepancies between patient county of residence and hospital location, and HRR-level analysis will lead to imperfect determinations of HRRs with mask mandates in place. However, the robustness of the model results across these 2 types of analyses provides support to the claims raised within the study.

Second, the pre-trend coefficients of the event study models are not all insignificant, suggesting that the assumption of parallel trends may not be satisfied for the event studies models. The direction of the pre-trend coefficients suggests that states with mask mandates may have already been experiencing lower levels of hospitalizations prior to implementation. In addition, the pre-trends suggest that mask mandates were implemented as community cases were on the rise; thus, some of the observed decrease after the state issuing of mask mandates may be due to epidemiological trends in community transmission. Third, our study was limited to state-issued policies and does not account for mitigation policies issued by local governments or individual businesses. For example, some states allowed local governments to issue mask mandates if the state did not implement one, and some counties responded by issuing mask mandates. Finally, we cannot, with certainty, rule out other potential confounders that may have influenced both the timing of state-issued mask mandates and changes in COVID-19 hospitalizations. For example, while our model does control for other NPIs, CDC recommended other mitigation strategies along with masking, which included increasing testing, safeguarding people at risk for COVID-19 complications, provision of adequate personal protective equipment for workers, and hand hygiene.[2] Authorities that adopt mask mandates may have been more likely to adopt other recommendations as well.

Conclusion

This study demonstrated that state-issued mask mandates were associated with a reduction in COVID-19 hospitalizations across the United States during the earlier portion of the pandemic. As new variants of the virus cause spikes in COVID-19 cases, reimposing mask mandates in indoor and congested public areas as part of a layered approach to community mitigation may reduce the spread of SARS-CoV-2 and lessen the burden on our health care system. Public health officials may want to consider referencing CDC's COVID-19 Community Level dashboard for current information on both their community's COVID-19 hospitalizations and the potential strains on their local health systems when making decisions about reimplementing community prevention strategies.[24]

Implications for Policy & Practice

- State-issued mask mandates were associated with a reduction in COVID-19 hospitalizations across the United States.
- Reimposing mask mandates during periods of high transmission in indoor and congested public areas as part of a layered approach to community mitigation may reduce the spread of COVID-19 and lessen the burden on our health care system.
- Public health officials may want to consider referencing CDC's COVID-19 Community Level dashboard for current information on both their community's COVID-19 hospitalizations and the potential strains on their local health systems when making decisions about reimplementing community prevention strategies.

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