Statewide Interventions and Coronavirus Disease 2019 Mortality in the United States: An Observational Study

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Methods. To determine whether later distancing interventions were associated with higher mortality, we performed a state-level analysis in 55,146 COVID-19 nonsurvivors. We tested the association between timing of emergency declarations and school closures with 28-day mortality using multivariable negative binomial regression. Day 1 for each state was set to when they recorded their first death, delays in declaring an emergency (aMRR 1.05; 95% CI, 1.01–1.09; P = .020) or school closures (aMRR 1.06; 95% CI, 1.03–1.09; P < .001) were associated with more deaths. Results were unchanged when excluding New York and New Jersey.

Conclusions. Later statewide emergency declarations and school closure were associated with higher Covid-19 mortality. Each day of delay increased mortality risk 5 to 6%.

Keywords. pandemic; SARS-CoV-2; coronavirus; social distancing; nonpharmaceutical interventions.
METHODS

Study Design
This was an ecologic study of publicly available data. The protocol was reviewed by the Children’s Hospital of Philadelphia institutional review board and deemed exempt from further review or oversight (institutional review board 20-017546). COVID-19 cases and deaths were obtained from the Johns Hopkins Center for Systems Science and Engineering Coronavirus Resource Center [9], a web-based tracker that records cases and mortality in the United States starting January 21, 2020. State-level demographic characteristics for confounder selection were extracted from the 2019 American Community Survey from the Census Bureau (www.census.gov). Timing of emergency declarations and statewide school closures were determined based on official press releases by states and governors.

Population
This was a decedent-only analysis of attributed COVID-19 deaths in the Hopkins Coronavirus Resource Center between January 21, 2020, and April 29, 2020 (n = 55,146 nonsurvivors). We chose to analyze decedents given the relatively low and variable rates of testing between states [10, 11], making number of cases unreliable. We reasoned that eventual COVID-19 nonsurvivors were more likely to have experienced severe infection and have undergone testing, thereby making this the most accurate of available metrics to track pandemic spread.

Definitions
Our coprimary exposures were the number of days between a state experiencing ≥ 10 COVID-19 deaths (standardized across states as day 1) and implementation of a statewide emergency declaration (day of emergency declaration minus day 1), and separately school (kindergarten through grade 12) closure (day of school closure minus day 1). We chose emergency declarations and school closures as the primary exposures because they were unambiguous interventions. Other distancing measures, such as bans on public gatherings, closure of nonessential businesses, and shelter-in-place orders were variably implemented between states, using divergent definitions, thresholds for maximum group sizes, and carve out exemptions.

The primary outcome was COVID-19 mortality on day 28. We chose the timepoint of 28 days because we reasoned that, if a statewide emergency declarations and school closures impacted mortality, then several weeks would be required to allow for a reduction in transmission, hospitalizations, and mortality.

Potential state-level confounders considered a priori were 2019 population, population density, percent of the population < 18 years of age, percent ≥ 65 years of age, percent Black, percent Hispanic, and percent below census-designated poverty threshold. We included the country-level confounder of census-designated division, which divides the country into nine geographic regions.

RESULTS
At the time of analysis on April 29, 2020, 37 of 50 states had experienced ≥ 10 deaths by April 2, 2020, thus ensuring availability of 28-day mortality. These 37 states composed the cohort for our primary analyses (Tables 1 and 2). Timing of emergency declarations and school closing were highly correlated (r = 0.84, P < .001). States declared an emergency at a median
of -14 (interquartile range [IQR] -18, -13) days relative to experiencing \( \geq 10 \) COVID-19 deaths, with all 37 states declaring an emergency before recording at least 10 deaths. States implemented school closures at a median of -9 (IQR -11, -4) days relative to experiencing \( \geq 10 \) COVID-19 deaths, with 32 of 37 states (86%) closing schools before experiencing at least 10 deaths. States declaring emergencies and closing schools earlier had a lower population, but were otherwise comparable to states closing schools later.

**Association Between Emergency Declaration and Mortality**

After adjusting for confounders, later emergency declaration was associated with higher mortality (Figure 1A). Assigning the day that a particular state had \( \geq 10 \) COVID-19 deaths as day 1, every day a state delayed declaring an emergency increased 28-day mortality by 5% (MRR 1.05; 95% CI, 1.00–1.09). When assigning day 1 as the day that a state experienced its first COVID-19 death and using data from all 50 states until April 29, 2020 (Figure 1B), mortality increased by 5% (MRR 1.05; 95% CI, 1.01–1.09) for every day of delay. Results were consistent when excluding New York and New Jersey from both analyses (Figures 1C and 1D), with later declaration of emergency associated with higher mortality risk.

**Association Between School Closings and Mortality**

Later implementation of a statewide school closure was similarly associated with higher mortality (Figure 2A). Assigning the day that a particular state had \( \geq 10 \) COVID-19 deaths as day 1, every day a state delayed implementing a school closure, 28-day mortality risk increased by 5% (MRR 1.05; 95% CI, 1.01–1.09). When assigning day 1 as the day that a state experienced its first COVID-19 death and using all available data from all 50 states until April 29, 2020 (Figure 2B), for every day a state delayed implementing a school closure, final mortality increased by 6% (MRR 1.06; 95% CI, 1.03–1.09). Results were consistent when excluding New York and New Jersey from both analyses (Figures 2C and 2D), with later implementation of school closures associated with higher mortality risk.

### Table 1. Characteristics of States Stratified by Tertile of When, Relative to Experiencing at Least 10 COVID-19 Deaths, Statewide Emergency Declarations Were Made

| States | Earliest (n = 13) | Middle (n = 15) | Late (n = 9) | P Value for Trend |
|--------|------------------|----------------|-------------|------------------|
| Governor party | Democratic | Republican | Democratic | Republican |
| Population | 5,391,506 ± 3,388,379 | 6,101,328 ± 3,453,891 | 18,329,049 ± 11,970,560 | .006 |
| Population density (per square mile) | 214 ± 197 | 183 ± 201 | 275 ± 299 | .682 |
| Demographics (%) | | | | |
| > 18 y | 22.1 ± 1.3 | 22.6 ± 1.7 | 22.5 ± 1.7 | .796 |
| ≥ 65 y | 16.7 ± 1.0 | 16.8 ± 1.0 | 15.4 ± 2.2 | .032 |
| Black | 14.6 ± 8.9 | 13.0 ± 9.4 | 15.9 ± 10.7 | .913 |
| Hispanic | 8.7 ± 3.6 | 11.0 ± 9.1 | 21.6 ± 12.0 | .015 |
| Poverty | 13.4 ± 2.6 | 13.0 ± 2.6 | 13.0 ± 2.9 | .758 |

### Table 2. Characteristics of States Stratified by Tertile of When, Relative to Experiencing at Least 10 COVID-19 Deaths, Statewide School Closure was Implemented

| States | Earliest (n = 14) | Middle (n = 11) | Late (n = 12) | P Value for Trend |
|--------|------------------|----------------|-------------|------------------|
| Governor party | Democratic | Republican | Democratic | Republican |
| Population | 5,089,825 ± 2,688,607 | 6,757,020 ± 4,350,053 | 13,582,179 ± 11,383,133 | .012 |
| Population density (per square mile) | 197 ± 192 | 222 ± 228 | 234 ± 268 | .730 |
| Demographics (%) | | | | |
| > 18 y | 22.4 ± 1.3 | 21.4 ± 1.5 | 22.7 ± 1.5 | .792 |
| ≥ 65 y | 16.6 ± 1.0 | 17.0 ± 1.1 | 15.7 ± 2.0 | .112 |
| Black | 16.1 ± 9.0 | 12.1 ± 9.6 | 14.0 ± 9.9 | .457 |
| Hispanic | 10.2 ± 7.0 | 10.7 ± 8.1 | 17.7 ± 12.5 | .129 |
| Poverty | 13.7 ± 2.7 | 12.7 ± 2.7 | 12.9 ± 2.8 | .388 |
Per Capita Analysis

When analyzing deaths per million as the primary outcome (Supplementary Figure 2), later implementation of emergency declarations was associated with higher mortality (MRR 1.03; 95% CI, 1.00–1.07), although this did not reach a traditional threshold for statistical significance ($P = .077$). Later implementation of statewide school closure was similarly associated with higher mortality (MRR 1.04; 95% CI, 1.01–1.07), which attained statistical significance ($P = .014$). Results were similar when excluding New York and New Jersey (Supplementary Figure 2B and 2D).

Regional Analysis

Because different regions of the United States experienced local epidemics, we assessed the cumulative death curves for each census-designated division (Supplementary Figure 3). Curves grew in all divisions, without evidence for plateauing. Census divisions 2 and 3 were among the latest of the 9 divisions to implement statewide emergency declarations, whereas divisions 4 and 8, which showed the slowest increase in deaths, were the 2 earliest.

DISCUSSION

States implementing emergency declarations or school closures later in the course of the pandemic experienced higher COVID-19 mortality, with each day of delay increasing mortality risk 5%–6%. This effect size was attenuated when measured as deaths per million, but still consistent with lower mortality with earlier statewide declarations. To our knowledge, this is the first demonstration of an association between statewide social distancing orders and mortality during COVID-19. Our results support early social distancing as a nonpharmaceutical intervention for reducing mortality.
Our study design and results do not directly implicate timing of either emergency declarations or school closings specifically as causal for reduced mortality, although causality is plausible. Emergency declarations, for example, have been shown to reduce social contacts. In a time-series analysis conducted by the National Bureau of Economic Research during the early weeks of COVID-19, state-level emergency declarations had the largest reduction in within-state mixing [13]. Thus, early state-level social distancing measures, including declaration of an emergency, may have contributed to reducing the spread of COVID-19, and by extension lower mortality.

The causality of timing of school closures on COVID-19 mortality is even less certain. Although SARS-CoV-2 appears not to cause as severe a disease in children [14, 15], children are potential asymptomatic carriers. In an analysis of laboratory-confirmed cases in the United States up to April 2, 2020, 27% of patients < 18 years of age were completely asymptomatic, compared with 7% of patients 18–64 years of age [16]. Modeling of influenza and a review of nonpharmaceutical interventions for 2003 SARS suggested that school closings are effective at reducing transmission between children, but only modestly affected transmission in the larger population, particularly if children were not disproportionately affected by the virus [17, 18]. However, school closings also prompt additional social distancing measures as caretakers reduce their workplace presence and travel, causing indirect social distancing and improving overall population transmission rates [19–23]. In the aforementioned National Bureau of Economic Research time-series analysis, school closing orders had negligible impact on within-state mixing, but reduced interstate travel by 10% [13]. Thus, school closings may directly reduce SARS-CoV-2 transmission rates by reducing contact among asymptomatic.
pediatric carriers, and indirectly via changing contact patterns between adults. Last, because this study is occurring early in COVID-19, it is possible that the efficacy of both emergency declarations and school closings are not in reducing total eventual COVID-19 mortality, but in reducing peak infection rates and improving hospital surge capacity [24].

Alternatively, and equally plausibly, both emergency declarations and the timing of school closures may be a proxy for the degree to which a state began to officially and unofficially implement significant social distancing [13]. At the time of analysis, all states had declared a statewide emergency, with 43 of 50 declaring before their first recorded COVID-19 death. Similarly, all had closed schools, and 41 of 50 states had a shelter-in-place order. In all but 2 cases, school closures preceded more restrictive shelter-in-place orders, with these orders occurring simultaneously for 2 states. Emergency declarations and school closures were among the first social distancing measures implemented in the United States. Thus, our results may reflect how quickly states responded to news about the size and severity of the spreading pandemic, with emergency declarations and school closures being among the first official nonpharmaceutical interventions, rather than protective effects specific to either intervention itself.

The majority of states implemented statewide school closures, and all states declared emergencies, before experiencing 10 COVID-19 deaths. Hence, the time to declaring an emergency or implementing school closure relative to how we defined day 1 could have either a positive or a negative value. States implementing earlier were likely responding to the rapid increase in cases being reported in the early hotspot states. This is consistent with data suggesting that early intervention in an exponentially growing pandemic is more efficacious than later interventions [5]. Our choice of death as an endpoint was due to concerns about inadequate and imprecise testing, thereby making counts of cases imprecise and highly variable between states. However, death is a lagging indicator, and increased time between these early interventions and eventual nonsurvival can result in imprecise effect estimates. Reassuringly, our conclusions remained unchanged in all analyses performed.

States that implemented emergency declarations and school closings later were more populous, and included the early hotspots of Washington, California, and New York. It is likely that COVID-19 had already attained a foothold in these states, and that subsequent states had the advantage of following their lead after witnessing the exponential increase in cases. This could lead to confounding in our analyses because there were more deaths in these more populous hotspots. We attempted to control for this in three ways. First, we adjusted for state population, population density, and census-designated geographic division. Next, we designated day 1 to start at a fixed number of deaths to analyze states at the same point in the pandemic. Finally, given the 4-fold higher mortality in the New York City metropolitan area, we performed analyses excluding New York and New Jersey. Although our analysis using deaths per capita as an outcome, rather than deaths, provided an attenuated effect size, the direction of the effect was still in favor of earlier nonpharmaceutical intervention orders.

Our study has limitations. Both of our exposures were measured at the state level, whereas local school districts also closed schools of their own accord before state orders. However, this was estimated to only affect ~16% of the population [13]. Death rates were based on publicly available data derived from inconsistent testing using assays with imperfect test characteristics and uneven state-level reporting; thus, both exposure and outcome risk being misclassified. When reliable testing and excess mortality data are available, an analysis using those data may yield more precise estimates of the efficacy of early statewide interventions on COVID-19 mortality. Additionally, we restricted analysis to the early weeks of COVID-19 because of concerns regarding accuracy of mortality data after May 1, 2020, as COVID-19 and social distancing continued to be politicized in the United States. Indeed, multiple states started reopening in the first weeks of May, and in some cases changed the method and timing of publicly reporting cases and deaths. Because of data limitations, we were unable to adjust for potentially important confounders such as outbreaks in long-term care facilities, which may have both accelerated the spread of SARS-CoV-2 and served as an impetus for physical distancing policies. State-level variation in access to healthcare and availability of hospital and intensive care unit resources were not included, which could also bias the results. Our data do not explore the association between duration of school closing orders and outcomes. However, the lesson of the 1918–1919 influenza pandemic is instructive: among 43 cities investigated, no city experienced a second peak of infections while the first set of nonpharmaceutical interventions were in effect, whereas in cities that lifted initial restrictions, death rates increased [5]. Finally, ecologic studies of group-level interventions cannot apply to individuals, and we have no metrics of either state- or individual-level adherence to social distancing in this study. However, our study satisfies several criteria for causality between timing of early interventions and mortality, including mechanistic plausibility, prior knowledge, temporal relationship, a dose-dependent effect (earlier vs later orders), and strength and consistency of the association. These results also confirm the utility and necessity of early nonpharmaceutical intervention to reduce mortality in COVID-19, and may serve to increase acceptance of social distancing measures by the lay public and by policymakers.

CONCLUSION

We provide evidence of an association between earlier statewide nonpharmaceutical interventions of social distancing and
lower mortality in the early weeks of COVID-19. Specifically, each day of delay in a state declaring an emergency or closing schools increased mortality risk by 5%–6%.

**Supplementary Data**

Supplementary materials are available at Clinical Infectious Diseases online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

**Notes**

**Financial support.** This work was supported by the National Institutes of Health K23-HL136688 (N.Y.), R01-HL148054 (N.Y.), and R00-HL141678 (M.O.H.)

**Potential conflicts of interest.** A.V. reports grants from Robert Wood Johnson Foundation, National Institutes of Health, Commonwealth of Kentucky, and Donaghue and Rx Foundations, outside the submitted work. M.H. reports grants from the National Institutes of Health, outside the submitted work. All other authors declare no conflicts of interest. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

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