Interstate variability in covid-19 infection and death rates: Do climate, health conditions, and distancing policies matter?

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Abstract

A comprehensive model to explain variation across states in COVID-19 outcomes indicated that improvements in social distancing, intermediate spring relative humidity and temperature, and lower concentrations of elderly residents were associated with lower rates of infection and mortality as well as changes over time. These influences were observed after accounting for testing prevalence. Findings indicate the benefits of continued preventive efforts by states and the value of tailoring resources at multiple levels of risk.

Keywords: Corona virus, COVID-19, Infection, Mortality.

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Introduction

Since the beginning of the coronavirus disease 2019 (COVID-19) pandemic, the incidence of infection in the United States has varied widely across states. In mid-April 2020, the number of confirmed infections per 100,000 residents ranged from 41 to 1,294 [1]. By early August, the range widened from 206 to 2,769. A similar pattern has occurred for rates of death [1]. Among the factors empirically identified that may account for this variability are differences in demographic characteristics such as age and socioeconomic status, population health conditions and behaviors, outdoor temperature and humidity levels, and compliance to statewide orders on social distancing [2-6]. In the first study, to my knowledge, encompassing these and other factors together, a comprehensive model of COVID-19 infection and mortality is tested to explain variability among the 50 states and the District of Columbia (DC).

Methods

Data Sources and Variables

Publicly available state-level data are used on the cumulative number of infections and deaths to August 7th, 2020 from state departments of health and the Centers for Disease Control and Prevention as aggregated by the COVID Tracking Project [1]. For both infections and deaths, three COVID-19 measures were created for each of the 51 units: (a) proportion of the total number of tested individuals with this status, (b) total number of affected individuals per 100,000 residents based on the 2019 U. S. Census state population, and (c) residual change in number of affected individuals per 100,000 residents between April 21, 2020 and August 7, 2020.

Based on prior research, 13 correlates (predictors) were included in the model (Supplement). The three demographic characteristics were proportions of the state population aged 65 or above and of White race, and median household income. Population health conditions was the average percentage of the 2018 state population obese, diabetic, or hypertensive [7]. Climate data included four dichotomous indicators reflecting historically the top and bottom quintile states in average daily spring temperature (>58.0 'F or <44.0 'F; March-May) and spring relative humidity (A.M.; >75% or <52%) [8].

Three state-level policy and compliance indicators were issuance of stay-at-home orders during April and May, and increases in social distancing behaviors over pre-COVID-19 (Feb-March) levels by April 15 and August 7, 2020 using smartphone GPS location tracking data from Unacast [9]. Finally, testing rates and an indicator for COVID-19 data quality (outstanding *vs* all others) assessed reliability of reporting [1].

Statistical Analysis

The model was estimated by linear regression. Logarithmic transformations were unnecessary, as outcomes were normally distributed. Data analysis was conducted using IBM's SPSS statistics software version 26. All models included the cumulative total number of individuals tested per 100,000 to control for states' diagnostic responsiveness. Testing rates on August 7, 2020 varied from 9,555 to 36,751 (mean=17,693). P-values at the .05 level were significant.

Results

We describe key findings for cumulative infections and deaths separately. By August 7, the mean number of infections per 100,000 residents was 1,289 [1]. Six states did not issue statewide stay-at-home orders and only 12 showed substantial improvements in social distancing from February-March to August 2020.

Table 1 summarizes the estimated model for three measures of COVID-19 infection. As a proportion of the total tested individuals (Column 2), the following variables were significantly associated with lower rates of infection: increases in social distancing by August (Coeff. =-0.037; p-value =0.001), intermediate spring relative humidity (52% <rh< 75%; Coeff. (reversed)= -0.040; p-value = 0.002), low spring average daily temperature (<42 'F; Coeff. = -0.023; p-value=0.026)), and less than outstanding in reported data quality (Coeff. (reversed)= 0.026; p-value = 0.001). This pattern was consistent with the number of infections reported by August 7 (Columns 3 and 4).

For example, after adjustment states with the largest improvements in social distancing by August showed a reduction of 637 infections per 100,000 residents (Column 3). Those with low spring relative humidity levels linked to an increase of 673

***Table 1**. Regression Estimates for Cumulative Rates of COVID-19 Infection Across States by August 7, 2020.*

	Infections as a proportion of total number of tested individuals			**Number of infections per**100,000 state residents			**Residual change in number** infections per 100,000 state		
State-level model variable	**Coeff**	**SE**	**P-value**	**Coeff**	**SE**	**P-value**	**Coeff**	**SE**	**P-value**
Percent Age 65 and above	0.002	0.002	0.397	10.06	31.7	0.753	-12.0	32.0	0.709
Top 20%, daily spring temperature	0.023	0.011	0.046*	467.6	186.5	0.017*	483.1	178.3	0.010*
Bottom 20%, daily spring temperature	-0.023	0.010	0.026*	-448.8	169.4	0.012*	-323.4	172.2	0.068
Bottom 20%, spring relative humidity	0.040	0.012	0.002*	673.4	204.9	0.002*	629.7	196.7	0.003*
Improved social distancing (August)	-0.037	0.10	0.001*	-636.6	166.4	<0.001*	-518.0	168.4	0.004*
Improved social distancing (April)	0.009	0.009	0.347	-8.0	157.2	0.960	76.8	155.3	0.624
Stay-at-home order issued	-0.011	0.010	0.279	-303.6	171.4	0.095	-248.7	171.4	0.155
State data quality rating is high	0.026	0.007	0.001*	427.4	122.5	0.001*	374.8	119.6	0.003*
N of tests per 100,000 residents	-1.17^{e-6}	<001	0.060	0.043	0.010	<0.001*	0.026	0.013	0.050*
Model variance explained (adjusted)	0.640	-	-	0.673	-	-	0.701	-	-
Outcome mean (SD; unadjusted)	0.076 (0.035)	-	-	1289.3 (619.6)	-		1089.4 (Aug 7 – Apr 21	-	-

Note. For brevity, the following variables were included in the model but were not listed in the Table (they showed no significant associations): Percent White residents, Family income (median), Percent with health risk conditions, and High spring relative humidity. For Column 4, the coefficient for the lagged regressor (April 21, 2020 rate of infection) was 0.717 (SE = 0.336; p-value = 0.040). Health conditions include obesity, hypertension, and diabetes. Temperature and relative humidity are daily averages for March to May. For racial category of White (Caucasian), non White includes Black, Asian, and American Indian. State data quality is rated high (outstanding vs. all others). Stay-at-home orders from April through May included mandates and rules for entire state population (43 states and DC) or major metropolitan areas (Utah, Oklahoma). For Column 4 (residual change), the regressor "Number of infections per 100,000 state residents by April 21, 2020" is not shown

***Table 2**. Regression Estimates for Cumulative Rates of COVID-19 Mortality Across States by August 7, 2020.*

	Deaths as a proportion of the total number of positive cases			**Number of deaths per100,000 state residents**			**Residual change in number of** deaths per 100,000 state residents since April 21, 2020		
State-level model variable	**Coeff**	**SE**	**P-value**	**Coeff**	**SE**	**P-value**	**Coeff**	**SE**	**P-value**
Percent Age 65 and above	0.004	0.001	0.016*	5.4	2.3	0.027*	2.6	1.7	0.134
Top 20%, daily spring temperature	0.014	0.006	0.035*	29.7	10.8	0.009*	0.3	9.0	0.975
Bottom 20%, spring relative humidity	0.002	0.009	0.791	21.5	15.1	0.163	10.8	10.7	0.322
Improved social distancing (August)	-0.018	0.007	0.017*	-35.7	12.3	0.006*	-11.6	9.5	0.229
Improved social distancing (April)	-0.011	0.007	0.132	-19.7	11.6	0.097	-9.5	8.3	0.259
Stay-at-home order issued	0.005	0.008	0.559	-7.1	13.1	0.589	-2.1	9.2	0.820
State data quality rating is high	-0.002	0.005	0.657	15.1	9.0	0.104	10.4	6.4	0.113
N of tests per 100,000 residents	1.05^{e-6}	< .000	0.026*	0.003	0.001	<0.001*	0.001	0.001	0.252
Model variance explained (adjusted)	-0.416	-	-	0.517	-	-	0.761	-	-
Outcome mean (SD; unadjusted)	0.029 (0.020)	-	-	39.6 (37.6)	-	-	30.5 (Aug-Apr)	-	

Note. For brevity, the following variables were included in the model but were not listed in the Table (they showed no significant associations): Percent White residents, Family income (median), Percent with health risk conditions, and High and Low daily average spring temperature. In Column 4, the coefficient for the lagged outcome regressor (April 21 death rate) was 1.9 (SE = 0.3; p < 0.001.)Health conditions include obesity, hypertension, and diabetes. Temperature and relative humidity are daily averages for March to May. For racial category of White (Caucasian), non White includes Black, Asian, and American Indian. Data quality is rated high (outstanding vs. all others). For Column 4 (residual change), the regressor "Number of infections per 100,000 state residents by April 21, 2020" is not shown--

infections per 100,000 residents. This pattern remained for the residual change model (Column 4).

Table 2 shows parallel results for cumulative death rates. The most consistent associations were social distancing improvements by August (Coeff.= -0.018; p-value = 0.017; Column 2), proportion age 65 and above (Coeff.= 0.004; p-value=0.016), and high spring relative humidity (Coeff.=0.014; p-value = 0.035). Each 1 percentage point increase in states' 65 and older residents was associated with a 0.4% increase in death rates as a proportion of positive tests (p-value=0.024).

The explanatory power of the model was relatively high (R^2, 42% to 76%). A variety of robustness analyses did not alter the pattern of findings.

Discussion

Advancing beyond previous studies [3-5], the assessed model included a comprehensive set of factors and covered the most recent time period when infection and death rates accelerated.

The most consistent factors accounting for interstate variation in infection and death were improvements in social distancing from pre-COVID-19 levels, the climate elements of spring humidity and temperature, and for death rates, the share of state population age 65 and above. For the GPS social distancing measure, states showing the largest increases in distancing had a rate of infection of 4.6% compared to 8.3% for other states. This is a 45% reduction. For rate of death, the reduction was 54%. Findings also dovetail with a recent virology review supporting the benefits of intermediate levels of humidity and temperature for reducing COVID-19 transmission [10].

Conclusion

In summary, a substantial portion of interstate variability in COVID-19 infections and deaths can be explained by compliance on social distancing, climate, aging demographics, and testing. These factors direct attention to the added value of continuing preventive measures at the state level to limit the spread of infection and resource investments that are tailored to states with demographic and climate profiles most susceptible to increased COVID-19 risk.

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Conflict of Interest

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Author Biographical Statement

Dr. Reynolds is a professor in the Institute of Child Development and Director of the Human Capital Research Collaborative at the University of Minnesota. He studies health policy, methodology, human development, and multi-level influences on family and community development.

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