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Mask Mandate Prevented COVID-19 Deaths in Minnesota

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As the number of COVID-19 deaths in the US increased, various policies were enacted in an effort to slow the spread of the pandemic. As sufficient data accumulate over time, the impact of policy on public health outcomes may be statistically evaluated. The present paper uses ODA to evaluate the hypothesized ability of Minnesota's limited mask mandate (MM) to reduce the daily number of COVID-19 deaths. Validity sensitivity analysis showed that chance-corrected reduction in the number of daily deaths began the day after the MM, and maximum reduction occurred 20 days after the MM.

As of October 15, 2020, the COVID-19 pandemic has killed over 217,000 people in the US.[1] This number already greatly exceeds the number of US troops killed in action (116,991) in the European Theater of the Second World War.[2] In addition to its historic lethality, this pandemic has drastically impacted economic activity, producing an annualized US GDP contraction of over 30%, which is the largest decline since the Great Depression.[3]

Several factors which made it difficult to determine and establish effective policy to combat this pandemic include pseudoscience[4] and cultural factors.[5] A patchwork of public policies and conflicting public advocacy add additional obstacles to discerning and implementing useful interventions.[6] And, recent research reports that the efficacy of MM policy evaluated using data aggregated from multiple US States yields misleading results attributable to the phenomenon known as Simpson's Paradox.[7,8] Instead, by disaggregating data and examining the impact of MM policy at the level of individual US states, it was shown that mask mandates reduced the number of new COVID-19 infections.[9]

This paper extends these prior findings, evaluating the effect of a MM on the number of *deaths* due to COVID-19 in Minnesota—which had the strongest *reduction* in number of *new* COVID-19 *cases* after the MM was issued.[9]

Methods

The daily number of COVID-19 deaths in Minnesota—in the 30 days *before* and the initial 50 days *after* the MM—was obtained from the publicly-available *New York Times* COVID-19-data repository.[10] Date of the Minnesota MM (June 1, 2020) was obtained from the Boston University COVID-19 US State policy (CUSP) database[11], and was confirmed by reference to the State of Minnesota Emergency Executive

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Order 20-63 mandating face masks for all public facing employees in Minnesota.[12]

ODA was first used to test the naïve *a priori* hypothesis that a statistically significant structural break in the number of deaths (the attribute) occurred immediately after (fewer deaths) *vs*. before (more deaths) the MM was issued (the class variable).[13]

Next, analysis was conducted to identify the amount of time (number of days) required for the MM to attain maximum effectiveness in reducing the number of COVID-19 deaths. The MM is hypothesized to reduce the number of COVID-19 deaths by decreasing the number of people infected with the virus: if disease lethality does not change, then fewer people will die. People who die of COVID-19 on the day that a MM is imposed (or soon thereafter) would have already been infected with the virus before the MM took effect, due to the time-course of the infection and associated symptomology. A MM is thus not necessarily expected to *immediately* exert its maximum impact on the number of COVID-19 deaths: rather, a temporal lag (or "*offset*") may be needed to assess the ultimate impact of the MM. Sensitivity analysis was thus conducted to assess the *strength* and *stability* of ODA models in training and in leave-one-out (LOO) cross-generalizability analysis, sequentially removing post-MM data from 1 to 21 days *after* the MM was issued from the analysis.[14-16]

Results

The first ODA analysis compared the number of deaths pre-MM (Days 1-30) *vs*. post-MM (Days 31-80). ODA evaluated the *a priori* hypothesis that the MM reduced the number of deaths. The training (total sample) model was: if ≤16 deaths predict post-MM, otherwise predict pre-MM. The model accurately predicted 41/50 (82.0%) of the post-MM days, and 24/30 (80.0%) of the pre-MM days, yielding ESS=62.0 which reflects a relatively strong model.[13,14] Model accuracy was stable in LOO validity analysis. This result suggests that, consistent with the confirmatory hypothesis, the MM reduced the number of fatalities in the subsequent 50 days.

Sensitivity analysis was conducted next to assess the number of days to *omit* ("offset") between pre- *vs*. post-MM assessment periods, in order to identify the ODA model yielding the maximum accuracy in discriminating pre- *vs*. post-MM days (Table 1). As seen, the model omitting 20 days had second-greatest predictive accuracy in training analysis (ESS= 86.7), and had greatest accuracy in LOO validity analysis (ESS=86.7). For this model, Figure 1 presents the number of fatalities before the MM (Days 1-30, left of the left-most dashed vertical line); during the 20 days after the MM began (Days 31-50, right of the left-most dashed vertical line); and thereafter (Days 51-80, right of the right-most dashed vertical line). The horizontal red dashed line indicates the ODA model cut-point of 11 deaths: as seen, prior to Day 31 only three observations fell below the ODA cutpoint (i.e., were misclassified), while after Day 51 one observation fell above the ODA cutpoint (i.e., was misclassified).

Discussion

In sensitivity analysis the accuracy of training models exceeded that of corresponding validity models except for four *LOO-stable* (i.e., equally accurate in training and validity analysis) models offset by 1, 2, 20, or 21-day lags. Note that the model cut-point indicating daily number of deaths decreased as the offset (number of days omitted from analysis) increased: this is consistent with individuals *who were already positive for COVID-19 prior to the MM* dying soon after the MM order was imposed. Although the MM immediately had a relatively strong effect[13] (50<ESS<75) in reducing the number of deaths, the ESS obtained in LOO analysis[14] met the criterion for a strong effect[13] (75≤ESS<90) for the models offset by 18 to 21 days (Table 1).

The present study thus reveals a strong impact of a limited MM in reducing COVID-19 deaths in Minnesota. The empirically identified

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Table 1: ODA Models for Sensitivity Analysis (All *p*<0.0001; LOO-Stable Models Are Highlighted)

		Training Analysis		LOO Analysis	
Omit #Days	Cutpoint	Accuracy (%)	ESS	Accuracy (%)	ESS
1	16	Pre: 24/30 (80.0) Post: 40/49 (81.6)	61.6	Pre: 24/30 (80.0) Post: 40/49 (81.6)	61.6
2	16	Pre: 24/30 (80.0) Post: 40/48 (83.3)	63.3	Pre: 24/30 (80.0) Post: 40/48 (83.3)	63.3
3	16	Pre: 24/30 (80.0) Post: 39/47 (83.0)	63.0	Pre: 24/30 (80.0) Post: 34/37 (72.3)	52.3
4	16	Pre: 24/30 (80.0) Post: 39/46 (84.8)	64.8	Pre: 24/30 (80.0) Post: 34/46 (73.9)	53.9
5	16	Pre: 24/30 (80.0) Post: 39/45 (86.7)	66.7	Pre: 24/30 (80.0) Post: 34/45 (75.6)	55.6
6	16	Pre: 24/30 (80.0) Post: 39/44 (88.6)	68.6	Pre: 24/30 (80.0) Post: 34/44 (77.3)	57.3
7	13	Pre: 25/30 (83.3) Post: 37/43 (86.1)	69.4	Pre: 24/30 (80.0) Post: 34/43 (79.1)	59.1
8	11	Pre: 27/30 (90.0) Post: 33/42 (78.6)	68.6	Pre: 24/30 (80.0) Post: 33/42 (78.6)	58.6
9	13	Pre: 25/30 (83.3) Post: 36/41 (87.8)	71.1	Pre: 24/30 (80.0) Post: 33/41 (80.5)	60.5
10	13	Pre: 25/30 (83.3) Post: 36/40 (90.0)	73.3	Pre: 24/30 (80.0) Post:33/40 (82.5)	62.5
11	11	Pre: 27/30 (90.0) Post: 33/39 (84.6)	74.6	Pre: 24/30 (80.0) Post: 33/39 (84.6)	64.6
12	11	Pre: 27/30 (90.0) Post: 33/38 (86.8)	76.8	Pre: 24/30 (80.0) Post:33/38 (86.8)	66.8
13	11	Pre: 27/30 (90.0) Post: 32/37 (86.5)	76.5	Pre: 24/30 (80.0) Post:32/37 (86.5)	66.5
14	11	Pre: 27/30 (90.0) Post: 32/36 (88.9)	78.9	Pre: 25/30 (83.3) Post: 32/36 (88.9)	72.2
15	11	Pre: 27/30 (90.0) Post: 31/35 (88.6)	78.6	Pre: 25/30 (83.3) Post: 31/35 (88.6)	71.9
16	11	Pre: 27/30 (90.0) Post: 30/34 (88.2)	78.2	Pre: 25/30 (83.3) Post: 30/34 (88.2)	71.6
17	11	Pre: 27/30 (90.0) Post: 30/33 (90.9)	80.9	Pre: 26/30 (86.7) Post: 29/33 (87.9)	74.6
18	11	Pre: 27/30 (90.0) Post: 30/32 (93.8)	83.8	Pre: 26/30 (86.7) Post: 30/32 (93.8)	80.4
19	11	Pre: 27/30 (90.0) Post: 30/31 (96.8)	86.8	Pre: 26/30 (86.7) Post: 29/31 (93.6)	80.2
20	11	Pre: 27/30 (90.0) Post: 29/30 (96.7)	86.7	Pre: 27/30 (90.0) Post: 29/30 (96.7)	86.7
21	11	Pre: 27/30 (90.0) Post: 28/29 (96.6)	86.6	Pre: 27/30 (90.0) Post: 28/29 (96.6)	86.6

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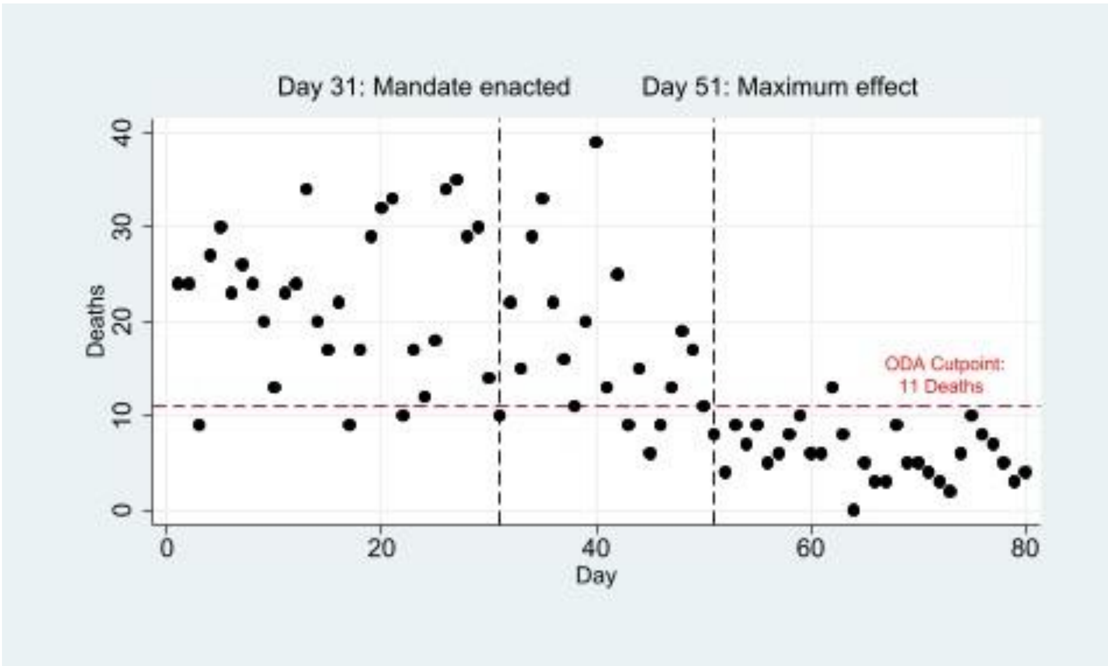
Figure 1: The Globally Optimal (GO) Model: Pre-MM (Days 1-30), Omitted (Days 31-50), and Post-MM (Days 51-80) Data for the ODA Model Yielding the Greatest ESS in LOO Analysis



delay between MM initiation and subsequent reliable reduction in the number of COVID-19 fatalities is consistent with prior independent studies of the median time from infection to death. For example, CDC estimates the average latency of infection to death is 19 to 23 days, depending on age.[16] Seen in Table 1, there is a strong effect between 18 and 21 days after the MM begins (in training analysis), and the effect is greatest at 20 days—halfway between the median times from infection to death of the two largest age groups analyzed by the CDC.[17]

It bears explicitly stating that the ODA models were generated with no assumptions made regarding when strongest effects would occur. As such their agreement with prior CDC research is indicative of their value. The ODA model evaluating effects 20 days after the MM reveals an ESS of 86.7 in training and in LOO validity: because this value falls between 75% and 90%, it is therefore said (by definition[13]) that the mandate had a *strong effect* on the number of deaths.

A major limitation of observational epidemiologic studies is that in the absence of additional data it is impossible to untangle to what extent other covariates and confounders modify observed effects.[18] Appropriate use of a mask is not necessarily the only driver of diminished fatalities—other factors affecting the success of policy designed to reduce the number of deaths include community/business shut down, social distancing, and continued use of masks so long as infections continue to occur.

It is no exaggeration to say that the MM in Minnesota saved hundreds of lives. Clearly there is a need for further study of policy impact on the COVID-19 pandemic. Researchers must examine specific state-, county, city, and "situation"-level policies on COVID-19 infection and deaths to bring the best policies to light.[9] Nevertheless, we should not ignore the policy-relevant findings achieved to date: (1) a MM policy can reduce the rate of COVID-19 infections[9]; (2) a more comprehensive MM mandate further increases mask use[19]; (3) as is shown herein, even

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limited MM programs can prevent COVID-19 deaths; and (4) the full benefit of a MM is not achieved immediately—the present findings show three weeks after the MM was imposed were needed to achieve dramatic, stable reduction in the number of fatalities in Minnesota.

These results support the value of a national policy mandating face masks in public settings: whereas the findings are insufficient to determine *how many* lives a national MM policy would save, preliminary results suggest that MM programs *will* save lives.

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Author Notes

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