Decrease in Hospitalizations for COVID-19 after Mask Mandates in 1083 U.S. Counties

[1,2]Dhaval Adjodah, [1]Karthik Dinakar, [3]Samuel P. Fraiberger, [4]George W. Rutherford, [4]David V. Glidden, [5]Monica Gandhi

[1]Massachusetts Institute of Technology, Media Lab, Cambridge, MA

[2]Center of Complex Interventions, Inc., Wellesley, MA

[3]Development Data Group, World Bank, Washington, DC

[4]Department of Epidemiology and Biostatistics, University of California, San Francisco (UCSF)

[5]Division of HIV, Infectious Diseases, and Global Medicine, Department of Medicine, University of California, San Francisco (UCSF)

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Corresponding author:
Monica Gandhi MD, MPH
Professor of Medicine, Division of HIV, Infectious Diseases and Global Medicine
Medical Director, Ward 86 HIV Clinic
995 Potrero Avenue, 4th floor
San Francisco, CA 94110
Monica.gandhi@ucsf.edu

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KEY POINTS

Question: Are mask mandates with an increase in population-wide facial masking in the U.S. associated with decreased hospitalizations due to COVID-19?

Findings: We hypothesize that facial masking, by reducing the viral inoculum to which the wearer is exposed, can lead to less severe disease if infection occurs. Using publicly-sourced epidemiological data, we assessed the change in proportion of hospitalizations due to COVID-19 as a result of the introduction mask mandates in 1083 counties across 49 states in the U.S. (representing 82% of the U.S. population). We found a statistically significant drop of up to 7.13 (95% CI: -4.19, -10.1) percentage points in COVID-19 hospitalizations following mask mandates, while controlling for age categories in the county, testing and cases normalized by population, and population mobility (as a way to control for other non-pharmaceutical interventions such as sheltering-in-place).

Meaning: Facial mask mandates seem to be associated with reduced severity of COVID-19 disease across the U.S.

ABSTRACT

Importance: Population-wide facial masking decreases COVID-19 transmission but may also decrease the severity of disease by reducing the viral inoculum to which the wearer is exposed. The mortality of COVID-19 infection decreased in the U.S. in the second wave over the summer of 2020 compared to the first, but reasons for declining severity of disease have not been fully elucidated.

Objective: To determine if facial mask mandates instituted in U.S. counties over the spring and summer of 2020 were associated with declining severity of infection as measured by the number of hospitalizations for COVID-19.

Design: Data on hospitalizations due to COVID-19; testing access determined by number of tests performed per day per 100,000 people; new cases per day normalized by population; measures of population mobility to control for other non-pharmaceutical interventions such as lockdowns, social distancing, and business closures; age categories in each census tract; and dates of masking mandates in U.S. counties were all obtained from open-sourced epidemiologic datasets. We used a staggered difference-in-difference study design to assess the impact of the introduction of mask mandates (defined as the treatment) on the proportion of hospitalizations due to COVID-19 per week from March 10-September 16, 2020.

Setting: U.S. counties with available full datasets on relevant COVID-19 metrics

Exposure: Mask mandates

Main outcome: Proportion of hospitalizations due to COVID-19

Results: Using data from 1083 counties (34% of U.S. counties, 82% of U.S. population) from 49 states, we found a statistically significant drop in hospitalization rates due to COVID-19 up to 12 weeks

following county mask mandates of 7.13 (95% CI: -4.19, -10.1) percentage points, after controlling for age categories by county, testing access, numbers of cases, and population mobility.

Conclusion and Relevance: Facial masking may decrease COVID-19 severity by decreasing the viral inoculum to which individuals are exposed. Mask mandates across 1083 counties in the U.S. in 49 states decreased hospitalization rates from COVID-19 even when controlling for other factors that could impact disease severity, including age, testing access, number of cases, and mobility (as a proxy for other non-Pharmaceutical interventions such as sheltering-in-place). This study adds to the growing evidence for the impact of masking on disease severity and on the utility of population-wide facial masking for COVID-19 pandemic control.

INTRODUCTION

The mortality associated with COVID-19 in the United States decreased with the second wave of infection seen in July-August 2020 compared to the first wave in April-May per the National Center for Health Statistics Mortality Reporting System.[1] Reasons suggested for this decreasing mortality include better treatments and hospital preparedness, younger age at diagnosis, higher testing rates (allowing for detection of more asymptomatic/mild infections), improved infection control and testing in nursing homes, and the virus mutating to a less pathogenic form.

Another factor that could be associated with the declining severity of disease is population-wide facial masking. Our group[2] and others[3-5] have suggested viral inoculum or dose as a factor associated with disease severity of SARS-CoV-2 and hypothesized that masking[2] and social distancing[5] could be reducing the size of the inoculum to which people who become infected are exposed. Although the Centers for Disease Control and Prevention recommended facial masking for the public on April 3, 2020, counties across the U.S. required masking for their population on different dates over the spring and summer of 2020 based on local surges in cases and local political forces.

The severity of disease with COVID-19 can be estimated by hospitalization rates since patients with severe disease require admission for inpatient oxygen and treatment. To assess the impact of county-based mask mandates on disease severity in the U.S., we analyzed COVID-19 hospitalization rates before and after mask mandates were introduced in 1083 U.S. counties across 49 U.S. states, comprising 82% of the U.S. population (as per the 2016 Census)[6].

METHODS:

Data for this analysis were obtained from the open-sourced Delphi's COVID-19 Surveillance Project dataset available as an application programming interface (API), the open-sourced COVID-19 Tracking Project, and the SafeGraph COVID-19 Data Consortium.[6] Mask mandate dates were obtained from a

published dataset sourced from county health departments' websites.[6] The introduction of a mask mandate by a U.S. county was defined as the start date of the "treatment" (the requirement to wear masks) and the outcome variable was the proportion of a county's hospital admissions due to COVID-19. Hospitalizations were identified by ICD-10 diagnosis code based on medical record summaries provided by health system partners to the COVID-19 Surveillance project.

Since counties across the U.S. enacted mask mandates at different dates or not at all, we adopted a staggered difference-in-difference study design.[7] Whenever a county was provided with both state and county-level mask mandates, we chose the earlier date as our treatment start date. We controlled for the total number of COVID-19 tests per 100,000 people (positive and negative PCR, antibody, and antigen tests) performed each day per state from the COVID-19 Tracking Project and the confirmed cases per 100,000 people from the COVID-19 Surveillance Project. We also included various measures of population mobility such as the proportion of cell phone users inferred to be staying at home from the COVID-19 Data Consortium to control for other non-pharmaceutical interventions such as lockdowns, sheltering-in-place, social distancing, and business closures. Finally, we used 2016 intercensal estimates[6] to control for county-level age, categorized as population counts within the following age brackets: 0-14 years, 15-44, 45-64 and >64 years. Our coefficient of interest is the effect of mask mandates every week on the proportion of hospitalizations due to COVID-19.[7] We include county codes and factored weekly timestamps in the regression to control for location and time fixed effects.

We did not impute missing values and only selected U.S. counties and date ranges with reliable data across datasets. Our final analytic dataset had data from 1083 counties (34% of U.S. counties, 82% of U.S. population per the 2016 population estimate[6]) from 49 states from March 10 to September 16, 2020 (**Figure**). Although we have reliable data since February 1st, we opted to use data starting on March 10th to prevent the initial noise from local governments scrambling to react to the pandemic from affecting our estimates.

RESULTS:

The **Figure** shows the change in hospitalizations secondary to COVID-19 in the 12 weeks prior to and the 12 weeks following mask mandates across the 1083 counties. There is a statistically significant drop in hospitalization rates due to COVID-19 up to 12 weeks following mask mandates with up to a 7.13 percentage point decrease (95% confidence interval (CI) -4.19 to -10.1), with a small pre-treatment effect that is likely explained by the fact that the population had already started masking prior to regional mandates. The change in the proportion of COVID-19-related hospitalizations was -0.54 percentage points (95% CI ±2.03) 2 weeks after the mask mandate, -1.45 (±2.64) at 4 weeks, -2.89 (±3.25) at 6 weeks, -4.06 (±3.85) at 8 weeks, -5.32 (±3.53) at 10 weeks, and -7.13 (±2.94) at 12 weeks. Sensitivity analysis showed that our results are not sensitive to any start date between February 1st and March 31st, 2020.

Finally, we ran the same analysis using the proportion of outpatient doctor visits as the outcome variable and observed a similar decrease at the inflection point of mask mandates (data not shown).

DISCUSSION:

We demonstrate that hospitalizations due to COVID-19 decreased after population-wide facial masking mandates were instituted across the U.S. using data from 1083 counties across 49 states from March to September 2020. These decreases were observed from the inflection point when mask mandates were instituted across counties and are independent of age distribution in the census tract, number of cases, mobility of the population, and testing access. Although testing for SARS-CoV-2 infection across the U.S. has increased, our models controlled for number of daily tests performed in each state and new confirmed cases per 100,000 people in the county, suggesting that the case-hospitalization rate (hospitalizations per case of COVID-19) is indeed decreasing. Since hospitalization for COVID-19 is a

marker of disease severity, mask mandates across the U.S. seem to be associated with decreased severity of SARS-CoV-2 infection over time.

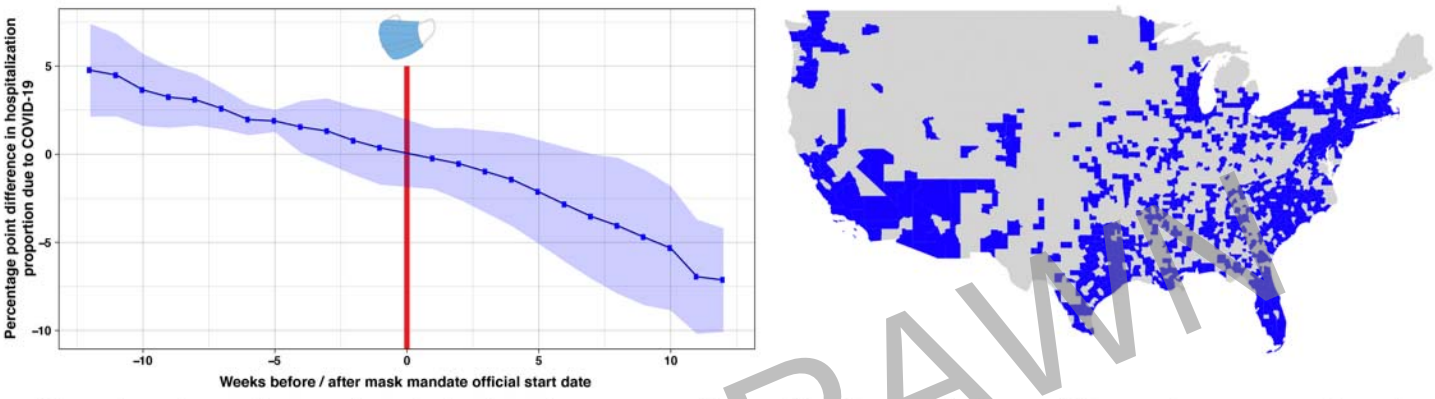
Facial masks filter out the majority of viral particles to which the wearer is exposed, decreasing transmission.[8] The severity of COVID-19 disease, once acquired, is likely dependent on a number of host factors (age, co-morbidities, etc.) and viral factors, including the viral inoculum. The association between inoculum size and disease severity has been seen in animal models with SARS-CoV-2.[9,10] Moreover, this dose-response relationship has been observed in a number of other infectious diseases, including *Salmonella* infection,[11] measles,[12] dengue,[13] and influenza.[14,15] Although younger age, better treatments, increased testing, and better infection control in nursing homes are all factors that could be contributing to lower case-hospitalization rates, our model controls for testing rates, cases, mobility (as a proxy for lockdowns, business closures, and social distancing in the region), and age categories in the counties. Moreover, treatments for COVID-19 are given for severe disease in hospitalized patients only, with no approved outpatient treatments yet available. Finally, although the D614G mutation in the spike protein of SARS-CoV-2 may increase infectiousness, there is no evidence that new mutations in the virus are less pathogenic.

The limitations of our analysis include not having data on compliance to facial masking by the populace in each county and not having access to the specific ages of hospitalized patients with COVID-19. Moreover, we could not grade the severity of infection beyond knowing whether a patient was ill enough to merit inpatient admission. Further statistical analysis such as a Bacon-Goodman Decomposition[16] of the time-factored treatment effect could help further understand treatment effect heterogeneity.

In conclusion, these data provide additional observational evidence for the hypothesis that facial masking may be associated with reduced severity of COVID-19 disease. The imputed mechanism is

that masks reduce the viral inoculum to which the wearer is exposed. Combined with social distancing, hand hygiene, and appropriate testing, this analysis adds to the evidence that population-wide facial masking is one of the pillars of the COVID-19 mitigation as we await a safe and effective vaccine.

Figure 1: Impact on Mask Mandates on COVID-19 Hospitalizations in 1083 U.S. Counties



Effect of mask mandates on hospitalizations for COVID-19 (controlling for population mobility, testing rates, confirmed cases per 100K, age categories) in 1083 U.S. counties (blue dots) indicated on U.S. map

References:

1. National Center for Health Statistics (NCHS) Mortality Reporting System, Centers for Disease Control and Prevention. Updated September 11, 2020; https://www.cdc.gov/coronavirus/2019-ncov/covid-data/covidview/09112020/nchs-mortality-report.html.
2. Gandhi M, Rutherford GW. Facial Masking for Covid-19 - Potential for "Variolation" as We Await a Vaccine. *N Engl J Med.* 2020.
3. Guallar MP, Meirino R, Donat-Vargas C, Corral O, Jouve N, Soriano V. Inoculum at the time of SARS-CoV-2 exposure and risk of disease severity. *Int J Infect Dis.* 2020;97:290-292.
4. Little P, Read RC, Amlot R, et al. Reducing risks from coronavirus transmission in the home-the role of viral load. *BMJ.* 2020;369:m1728.
5. Bielecki M, Zust R, Siegrist D, et al. Social distancing alters the clinical course of COVID-19 in young adults: A comparative cohort study. *Clin Infect Dis.* 2020.
6. **Publicly-available data sources**: US Census 2016 Population Estimates by Age, Sex, Race and Hispanic Origin: Available at: https://www.census.gov/programs-surveys/popest/technical-documentation/file-layouts.html; Delphi's COVID-19 Surveillance Streams (covidcast) API description: Available at https://cmu-delphi.github.io/delphi-epidata/api/covidcast.html; The COVID-19 Tracking Project: Available at: https://covidtracking.com/about; SafeGraph COVID-19 Data Consortium: Available at: https://www.safegraph.com/covid-19-data-consortium; Wright, A. et al. "Tracking Mask Mandates During the Covid-19 Pandemic." University of Chicago, Becker Friedman Institute for Economics Working Paper 2020-104 (2020). Available at: https://bfi.uchicago.edu/working-paper/tracking-mask-mandates-during-the-covid-19-pandemic; All open source data retrieved September 20, 2020.
7. Stevenson, Betsey and Justin Wolfers. "Bargaining In The Shadow Of The Law: Divorce Laws And Family Distress," Quarterly Journal of Economics, 2006, v121(1,Feb), 267-288. Available at: https://www.nber.org/papers/w10175.pdf.
8. Wang X, Ferro EG, Zhou G, Hashimoto D, Bhatt DL. Association Between Universal Masking in a Health Care System and SARS-CoV-2 Positivity Among Health Care Workers. *JAMA.* 2020.
9. Ryan KA et al. Dose-dependent response to infection with SARS-CoV-2 in the ferret model: evidence of protection to re-challenge. bioRxiv 2020.05.29.123810; doi: https://doi.org/10.1101/2020.05.29.12381.
10. Imai M, Iwatsuki-Horimoto K, Hatta M, et al. Syrian hamsters as a small animal model for SARS-CoV-2 infection and countermeasure development. *Proc Natl Acad Sci U S A.* 2020;117(28):16587-16595.
11. Glynn JR, Bradley DJ. The relationship between infecting dose and severity of disease in reported outbreaks of Salmonella infections. *Epidemiol Infect.* 1992;109(3):371-388.
12. Aaby P, Bukh J, Lisse IM, Smits AJ. Overcrowding and intensive exposure as determinants of measles mortality. *Am J Epidemiol.* 1984;120(1):49-63.
13. Nishiura H, Halstead SB. Natural history of dengue virus (DENV)-1 and DENV-4 infections: reanalysis of classic studies. *J Infect Dis.* 2007;195(7):1007-1013.
14. Memoli MJ, Czajkowski L, Reed S, et al. Validation of the wild-type influenza A human challenge model H1N1pdMIST: an A(H1N1)pdm09 dose-finding investigational new drug study. *Clin Infect Dis.* 2015;60(5):693-702.
15. Paulo AC, Correia-Neves M, Domingos T, Murta AG, Pedrosa J. Influenza infectious dose may explain the high mortality of the second and third wave of 1918-1919 influenza pandemic. *PLoS One.* 2010;5(7):e11655.

16. Goodman-Bacon, A.. Difference-in-differences with variation in treatment timing. No. w25018. National Bureau of Economic Research, 2018. Accessble at: https://www.nber.org/papers/w25018.

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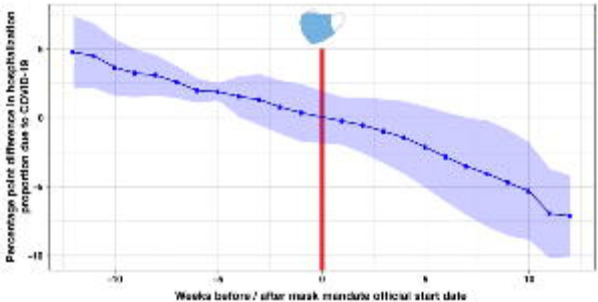

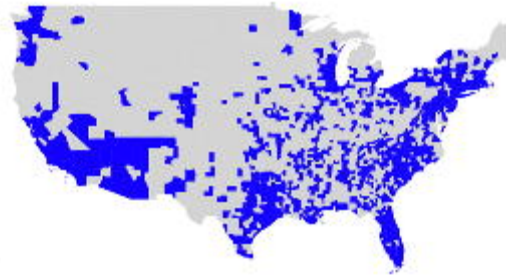

Effect of mask mandates on hospitalizations for COVID-19 (controlling for population mobility, testing rates, confirmed cases per 100K, age categories) in 1083 U.S. counties (blue dots) indicated on U.S. map