Associations of stay-at-home order and face-masking recommendation with trends in daily new cases and deaths of laboratory-confirmed COVID-19 in the United States

Jie Xu,[1] Sabiha Hussain,[2] Shi Wei,[3] Wei Bao,[4] Lanjing Zhang[5-7]
[1]Department of Infectious Disease, Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, China; [2]Department of Medicine, Rutgers Robert Wood Johnson Medical School, New Brunswick, NJ, USA; [3]Department of Pathology, University of Alabama at Birmingham, Birmingham, AL, USA; [4]Department of Epidemiology, College of Public Health, University of Iowa, Iowa City, IA, USA; [5]Department of Biological Sciences, Rutgers University Newark, NJ, USA; [6]Department of Pathology, Princeton Medical Center, Plainsboro, NJ, USA; [7]Department of Chemical Biology, Rutgers Ernest Mario School of Pharmacy, Piscataway, NJ, USA.

Correspondence: Lanjing Zhang, MD, Department of Pathology, Princeton Medical Center, 1 Plainsboro Rd., Plainsboro, NJ 08563. Email: lanjing.zhang@rutgers.edu

Running head: Policy and COVID-19 trends
Key words: Trend, incidence, coronavirus disease 2019, policy
Conflict of Interest Disclosures: No disclosures were reported.

Abstract

OBJECTIVE: To examine the associations of stay-at-home order and face-masking recommendation with trends in daily new cases and deaths of laboratory-confirmed coronavirus disease 2019 (COVID-19) in the United States

DESIGN: Piecewise log-linear modelling of temporal trends with turning-points, followed by quasi-experimental study on trend turning-point. Simulation studies were carried out to understand the outcomes under the scenarios if early-implementation and removal of stay-at-home order occurred.

SETTING: Population data in the United States

PARTICIPANTS: Residents in the U.S., who were affected by the stay-at-home and face-masking policies

MAIN OUTCOME MEASURES: Turning-points of the daily new cases and deaths of COVID-19, and COVID-19 time-varying reproduction numbers (Rt) in the U.S.

RESULTS: The number and the proportion of U.S. residents under SAHO increased between March 19 and April 7, and plateaued at 29,0829,980 and 88.6%, respectively. The trend in COVID-19 daily cases reduced after March 23 (P<0.001) and further reduced on April 3 (P<0.001), which was associated with implementation of SAHO by 10 states on March 23, and the Centers for Disease Control and Prevention's recommendation of face-masking, respectively. Similar turning points were identified in the trends of daily deaths with a lag time. The estimates of Rt based on the 3 reported mean serial-intervals of COVID-19 all started to decline on March 19, when SAHO was first implemented in the U.S. and declined faster after March 23. After a short plateau, Rt continued to decline after April 3 and fell below/around 1.0 on April 13.

CONCLUSIONS: There were 2 turning points of COVID-19 daily new cases or deaths in the U.S., which appeared to associate with implementation of SAHO and the CDC's face-masking recommendation. Simulation on early-implementation and removal of SAHO reveals considerable impact on COVID-19 daily new cases and deaths. These findings may inform decision-making of lifting SAHO and face.

The coronavirus disease 2019 (COVID-19) affected more than 660,000 people in the U.S.[1] In response, many states implemented the stay-at-home order (SAHO). The Centers for Diseases Control and Prevention (CDC) recommended also face-masking. Public health interventions were associated with reduction of SARS-CoV-2 transmission in China,[2] but the associations of SAHO and face-masking recommendation with COVID-19 epidemiology in the U.S. are unclear. We examined these associations using observed data and then performed simulations for outcomes under the scenarios if early-implementation and removal of SAHO occurred.

Methods

We extracted data about daily new cases and deaths of COVID-19 from theCOVID-19 Tracking Project, which tracked COVID-19 data since February 28, 2020.[3] Only the cases and deaths occurred from March 1 to April 20, 2020 in the 50 states and the District of Columbia were analyzed. New cases and deaths were defined as laboratory-confirmed positive cases or deaths which were reported by a state's public health authority for the data consistency and better data-quality.[3] Each of these state authorities reported its data in different format, while most, if not all, of them followed the reporting guidelines of the Centers for Diseases Control and Prevention (CDC). It is noteworthy that on April 14, 2020, the CDC updated its definition of positive cases and included probable-positive cases.[4] The impact of this change to the data released on April 20, 2020 would be minimal due to a short time-interval (many states have not adopted the criteria yet) and the confirmatory laboratory-test result. Therefore, the case/death numbers reported here might be smaller than those reported by others. For quality control of the released and curated data, the COVID-19 Tracking Project employed a 4-tier score system, which included 4 simple components, including reporting positive test results reliably, reporting negatives sometimes, for reporting negatives reliably and reporting all commercial tests. Based on the sum of these scores, each state corresponded to a letter grade A, B, C and D, with A for the best quality. All states scored A or B.

Several population-based factors were included in the multivariable piecewise log-linear regression analyses. Specifically, the timing of SAHO and populations of the states were obtained to calculate the number of subjects and the proportion of the U.S. population under SAHO on a given date.[5]. The proportion of daily positive results in all daily tests was obtained from the COVID-19 Tracking Project.[3]

The time-varying reproduction numbers (Rt) were defined as the mean number of secondary cases generated by a typical primary case at the time t in a population, and estimated using previously-reported serial-intervals[6-8] and the R package (Version 3.6.3).[2] Three-day moving averages of the Rt were reported. We estimated the segmental coefficients using piece-wise log-linear models and 2 presumptive turning-points. Simulation studies were performed using the prediction function. Statistical analyses were performed using Stata (version 15) and the Joinpoint program (NCI, version 4.7.0.0) with the Poisson Variance option. All *P* values were 2-sided, with a cutoff of .05 for significance.

Results

On March 19, 2020, the State of California started a stay-at-home order (SAHO) which affected 3,9512,223 (12.0% of the U.S. population) U.S. residents (**Figure 1**). The number and the proportion of U.S. residents under SAHO continued to increase until April 7, and plateaued at 29,0829,980 and 88.6%, respectively, afterwards.

The log-linear models used by Joinpoint program and Stata identified similar turning-points. The population and population-proportion under SAHO and the proportion of positive tests were not linked to daily new cases or death. The trend in COVID-19 daily cases reduced after March 23 ($P<0.001$) and further reduced on April 3 ($P<0.001$), which was associated with implementation of SAHO by 10 states on March 23, and the CDC's

recommendation of face-masking, respectively (**Figure 2**). Similarly, there were 2 turning-points in the trends of COVID-19 daily deaths, with lag time. Our simulation studies show early-implementation of SAHO would be associated with a significant reduction while removal of SAHO would be associated with a significant increase in daily new cases and deaths (**Figure 2**). The estimates of Rt based on the 3 reported mean serial-intervals of COVID-19 all started to decline on March 19, when SAHO was first implemented in the U.S. and declined faster after March 23 (**Figure 3**). After a short plateau, Rt continued to decline after April 3 and fell below/around 1.0 on April 13.

Discussion

We show two turning points of COVID-19 daily new cases or deaths in the U.S., which appeared to associate with implementation of SAHO and the CDC's face-masking recommendation. Simulation on early-implementation and removal of SAHO reveals considerable impact on COVID-19 daily new cases and deaths. Cautions thus are needed in decision-making of lifting SAHO, when weighing the health consequences and economic burden of SAHO.

Limitations included lag in COVID-19 reporting, under-testing of the potential patients and not reporting daily incidence. There were no significant changes in the U.S. population during the study-period. The daily new cases of COVID-19 thus should be proportional to its daily incidence in the U.S., but are easier to interpret than daily incidence. These findings may inform policy-making concerning SAHO and face-masking.

Figure Legends

Figure 1. The population under a stay-at-home order owing to the COVID-19 in the United States

Since March 19, 2020 when the State of California started a stay-at-home order (SAHO), the number and proportion of the U.S. residents under SAHO have increased until April 7 and plateaued afterwards.

Figure 2. Observed and Simulated Trends in Daily New Cases and Deaths of Laboratory-Confirmed Coronavirus Disease 2019 (COVID-19) in the United States between March 1 and April 30, 2020.

The Joinpoint analyses with Poisson variance model show that the 2 turning points of March 23 and April 3 divided the trends in U.S. COVID-19 daily new cases into 3 segments, with the coefficients of 31.69 (95% CI, 26.82 to 36.75, $P<0.001$), 9.75 (95% CI, 7.54 to 12.01, $P<0.001$), -0.90 (95% CI, -1.62 to -0.17, $P=0.02$), respectively. These turning points appeared to link to implementing a stay-at-home order (SAHO) by 10 states on March 23, and the CDC's face-masking recommendation on April 3. Similarly, the 2 turning points of April 3 and April 15 divided the trends in U.S. COVID-19 daily new deaths into 3 segments, with the coefficients of 25.06 (95% CI, 21.44 to 28.79, $P<0.001$), 5.22 (95% CI, 3.36 to 7.11, $P<0.001$), -7.90 (95% CI, -13.45 to -1.99, $P=0.01$), respectively. The simulated results on early-announcements of SAHO and face-masking recommendation and early-removals of SAHO are shown in A and C, and B and D, respectively. The partial removals of SAHO's coefficients(ß) may reflex the situations when some of the U.S. states lift the SAHO.

Figure 3. Estimated Effective Reproduction Number (Rt) Based on Laboratory-Confirmed Coronavirus Disease 2019 (COVID-19) Cases in the United States and the Reported Serial Intervals.

The effective reproduction number (Rt) was estimated using the previously-reported COVID-19 mean serial intervals (SI) of 7.5, 4.7 and 3.96 days, as well as the corresponding standard deviations (SD). The state-wide stay-at-home-order was first implemented by the state of California on March 19, 2020 (yellow dash line). Ten states had implemented a stay-at-home order by March 23, 2020 (green dash line), affecting 114,047,753 residents (37.45% of the U.S. population). The Centers for Disease Control and Prevention recommended face-masking on April 3, 2020 (blue dash line). These dates were linked to the declines of Rt's at the times of an increase or plateau of the Rt.

Author Contributions: Dr Zhang had full access to all of the data in the study and equally takes responsibility for the integrity of the data and the accuracy of the data analysis.

Concept and design: Xu, Zhang.

Acquisition, analysis, or interpretation of data: All authors.

Drafting of the manuscript: Xu.

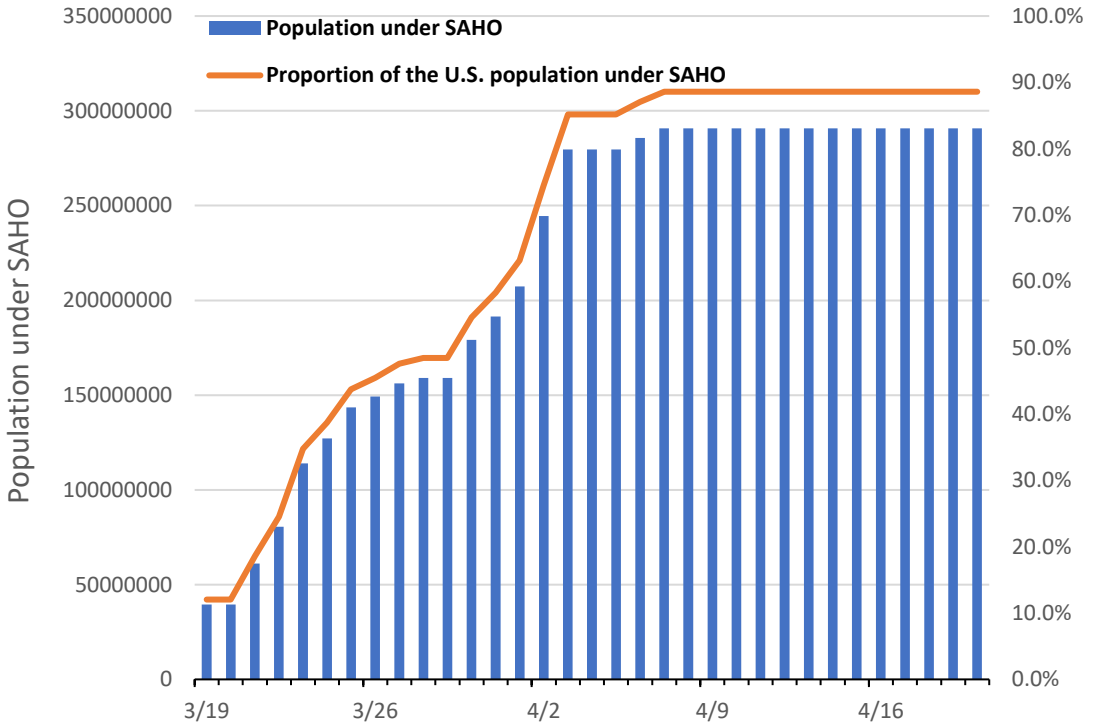
Critical revision of the manuscript for important intellectual content: All authors.

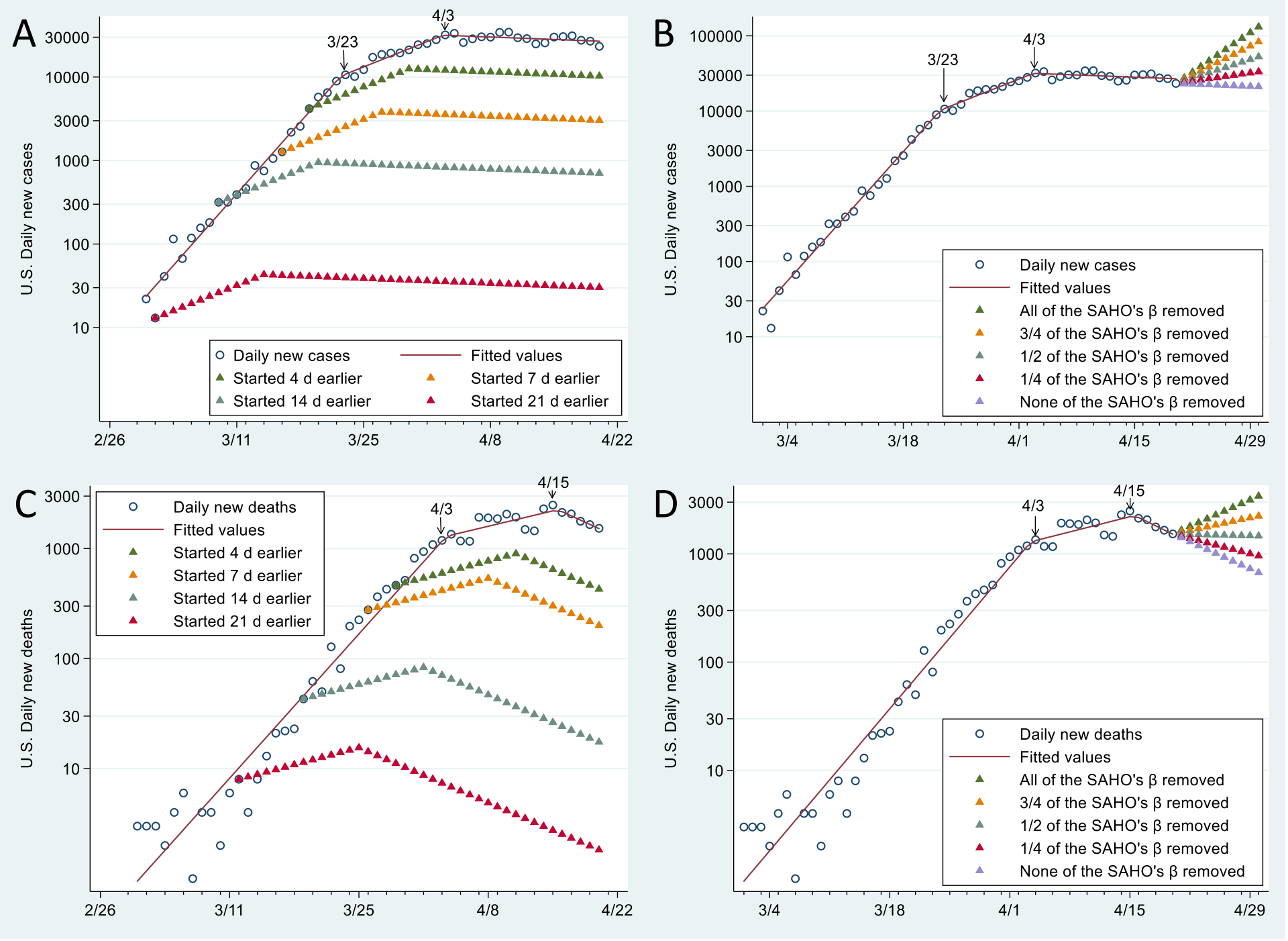
Statistical analysis: Zhang.

Supervision: Zhang.

References

1. Yuan X, Xu J, Hussain S, Wang H, Gao N, L Z. Trends and prediction in daily new cases and deaths of COVID-19 in the United States: An internet search-interest based model. *Explor Res Hypothesis Med.* 2020;5(2) doi: 10.14218/ERHM.2020.00023.
2. Pan A, Liu L, Wang C, et al. Association of Public Health Interventions With the Epidemiology of the COVID-19 Outbreak in Wuhan, China. *JAMA.* 2020 doi: 10.1001/jama.2020.6130.
3. The COVID Tracking Project. 2020; https://covidtracking.com/about-data. Accessed Apr 20, 2020.
4. CDC. Cases of Coronavirus Disease (COVID-19) in the U.S. 2020; https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/cases-in-us.html. Accessed Apr 20, 2020.
5. Wikipedia. U.S. state and local government response to the 2020 coronavirus pandemic. 2020; https://en.wikipedia.org/wiki/U.S._state_and_local_government_response_to_the_2020_coronavirus_pandemic. Accessed Apr 18, 2020.
6. Li Q, Guan X, Wu P, et al. Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus-Infected Pneumonia. *N Engl J Med.* 2020 doi: 10.1056/NEJMoa2001316.
7. Nishiura H, Linton NM, Akhmetzhanov AR. Serial interval of novel coronavirus (COVID-19) infections. *Int J Infect Dis.* 2020;93:284-286. doi: 10.1016/j.ijid.2020.02.060.
8. Du Z, Xu X, Wu Y, Wang L, Cowling BJ, Meyers LA. Serial Interval of COVID-19 among Publicly Reported Confirmed Cases. *Emerg Infect Dis.* 2020;26(6) doi: 10.3201/eid2606.200357.


Population under SAHO
Proportion of the U.S. population under SAHO
Population under SAHO
350000000
300000000
250000000
200000000
150000000
100000000
50000000
0
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
3/19
3/26
4/2
4/9
4/16


A
B
C
D
U.S. Daily new cases
U.S. Daily new deaths
3/23
4/3
4/15
Daily new cases
Fitted values
Started 4 d earlier
Started 7 d earlier
Started 14 d earlier
Started 21 d earlier
All of the SAHO's β removed
3/4 of the SAHO's β removed
1/2 of the SAHO's β removed
1/4 of the SAHO's β removed
None of the SAHO's β removed
Daily new deaths
2/26
3/11
3/25
4/8
4/22
3/4
3/18
4/1
4/15
4/29